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PRODUCTION SUITABILITY OF AN ELECTROFORM CONDUCTIVE WAX PROCESS FOR THE MANUFACTURE OF FLUIDIC SYSTEMS

Honeywell Inc.
Government and Aeronautical Products Division
Minneapolis, Minn. 55413

November 1975

Final Report for Period 5 November 1973 to 31 January 1975

Approved for public release;
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Prepared for

U. S. ARMY AVIATION SYSTEMS COMMAND
P. O. Box 209, Main Office
St. Louis, Mo. 63166

EUSTIS DIRECTORATE
U. S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY
Fort Eustis, Va. 23604

EUSTIS DIRECTORATE POSITION STATEMENT

The purpose of this three-phase program is to determine the production suitability of the Electroform Conductive Wax process in conjunction with existing conventional production processes for the manufacture of fluidic systems. The Electroform Conductive Wax process was developed to overcome problems of leakage and the inability of duplication associated with current methods used in fabricating fluidic components and systems. Use of this process in the laboratory has produced excellent results; therefore, this program is to demonstrate that fluidic components and systems can be produced in large quantities using production methods, production conditions, and production people with the same excellent results experienced under laboratory conditions. This report on the Phase I efforts describes the design, fabrication, and testing of the components and systems manufactured using the Electroform Conductive Wax process.

Mr. George W. Fosdick of the Systems Support Division served as the project engineer for this effort.

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Production Process

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This is a three-phase program to determine and demonstrate the production suitability of the Electroform Conductive Wax process in conjunction with conventional production processes for the manufacture of fluidic systems. During this phase, Phase I, an integrated amplifier-manifold hydrofluidic stability augmentation system using the Electroform Conductive Wax process was successfully designed, fabricated, and qualification tested, and a pilot production line using the Electroform Conductive Wax process was defined. The pilot production line includes all manufacturing, inspection,

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and assembly equipment necessary to produce the integrated amplifier-manifold hydrofluidic stability augmentation systems. During Phase II, the pilot production line will be set up and checked out by fabrication and test of these systems. The fabrication and test data is to be analyzed and process modifications are to be accomplished as necessary. During Phase III, a small "proof" production run is to be accomplished, component quality determined, and a Technical Data Package prepared.

PREFACE

This document is the final report on the first phase of a three-phase program conducted under Army Contract DAAJ02-74-C-0012. The program was administered under the direction of the Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, with Mr. G.W. Fosdick as the project engineer. The work was conducted during the period 5 November 1973 through 31 January 1975.

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SECTION I

INTRODUCTION

Most conventional production techniques are not readily adaptable to the manufacture of fluidic devices with small passageways, intricate configurations, close-tolerance requirements, and the need for sealed circuits. Consequently, the Electroform Conductive Wax (ECW) process was developed. Through various developmental programs, the ECW process has demonstrated the potential to accurately fabricate leakproof fluidic components. The object of this program is to determine the production suitability of the ECW process in conjunction with existing conventional processes for the manufacture of fluidic systems. This is a 30-month program divided into three phases. Phase I is the subject of this report and consists of the following major tasks:

- Design and develop an integrated amplifier-manifold circuit for use in the hydrofluidic yaw axis stability augmentation system (SAS) developed under Contract DAAJ02-72-C-0051 with the Eustis Directorate, USAAMRDL, Fort Eustis, Virginia.

- Perform qualification tests on the SAS system with the integrated amplifier-manifold circuit.

- Design a pilot production line for the fabrication of fluidic components using the ECW process and for the functional testing of the components.

In the remaining two phases of the program, ECW-processed fluidic components will be fabricated and tested, the results will be statistically analyzed, and a technical data package defining the SAS system and ECW process will be compiled.

SECTION II
SYSTEM DESIGN

CIRCUIT DESIGN

The circuit developed under this contract is functionally identical to that developed under Contract DAAJ02-73-C-0046, Hydrofluidic Yaw Stability Augmentation System Operational Suitability Demonstration. A schematic of the integrated circuit is shown in Figure 1. Amplifiers A1 and A3 have a high input impedance and are defined in Figure 2. A high input impedance results from the use of narrow control ports, which have an area only 40 percent as large as that on all other amplifiers in this circuit. Amplifiers A2 and A5 are the standard amplifier configurations, defined in Figure 2 as 10050019-101. This standard configuration has a setback in the region where the control flow impinges on the power flow. Amplifier A4, shown in Figure 2 as 10050019-103, is identical to the standard amplifier except that the setback has been eliminated. Amplifier configurations and their location in the circuit are the same for both the previous operational suitability program and the present producibility program. The only significant circuit difference in these two programs is that the in-line feedback resistors are replaced with resistance bridge networks to eliminate the need for extremely small orifices.

FEEDBACK RESISTOR DESIGN

The configuration of the feedback bridge resistor networks, defined in Figure 3, is electroformed on a baseplate as shown in Figure 4. Each bridge resistor assembly has three legs defined by A, B, and C of Figure 5.

Elimination of small contamination sensitive orifices was the primary objective of this design. Resistor elements are 0.015 inch by 0.015 inch, and as many as five are used in series to make each resistor leg. The unusual geometry on each side of the square restrictor holes is designed to dissipate the velocity head of the flow leaving the restrictor. Figure 5 is an example of a pair of bridge resistors used to provide negative feedback.

Resistance of a sharp-edged orifice has been calculated to be

$$R_s = \frac{\sqrt{\Delta P}}{51.6\ A} \qquad (1)$$

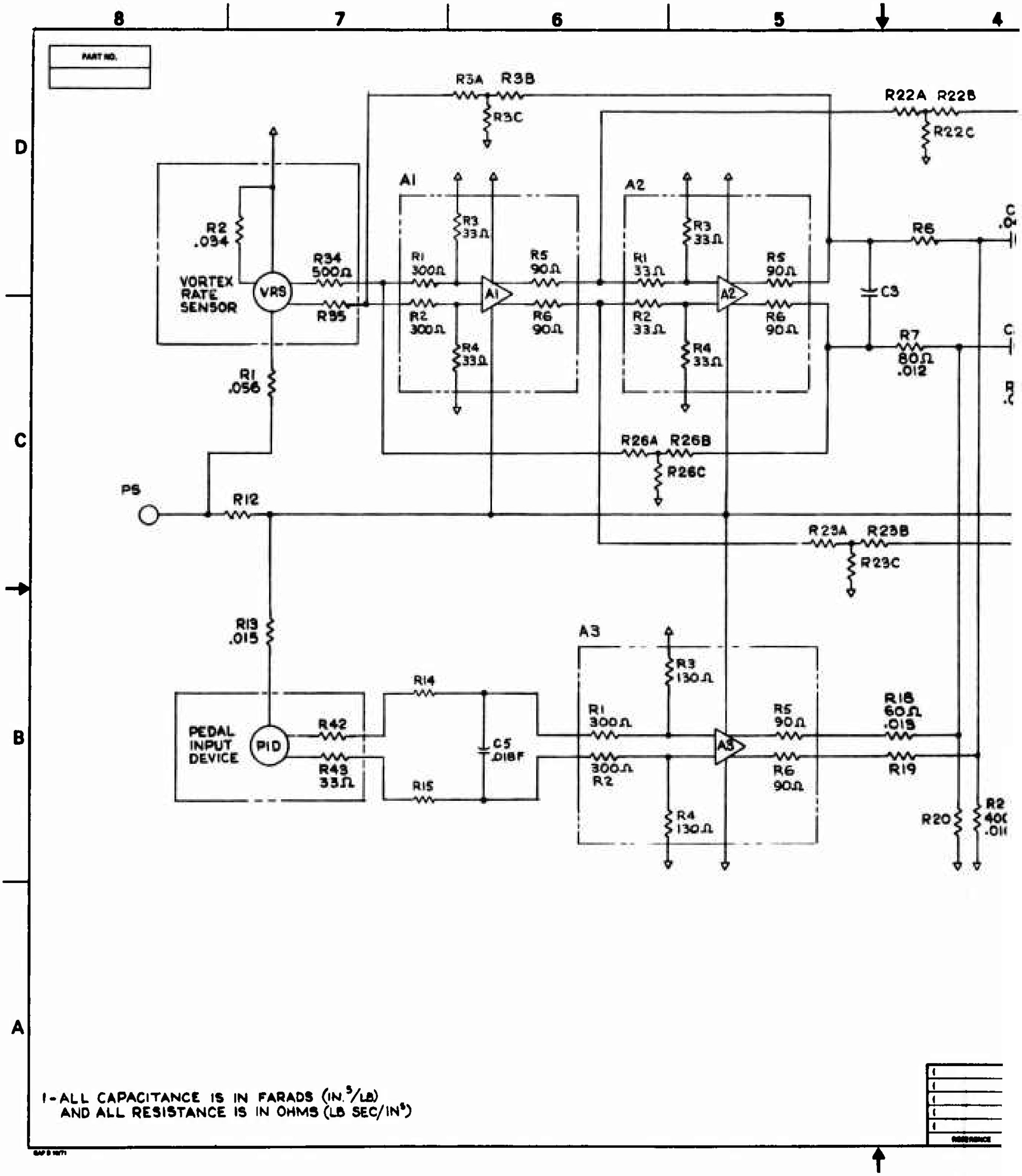

Figure 1. Schematic Diagram of the Yaw Axis Hydrofluidic SAS.

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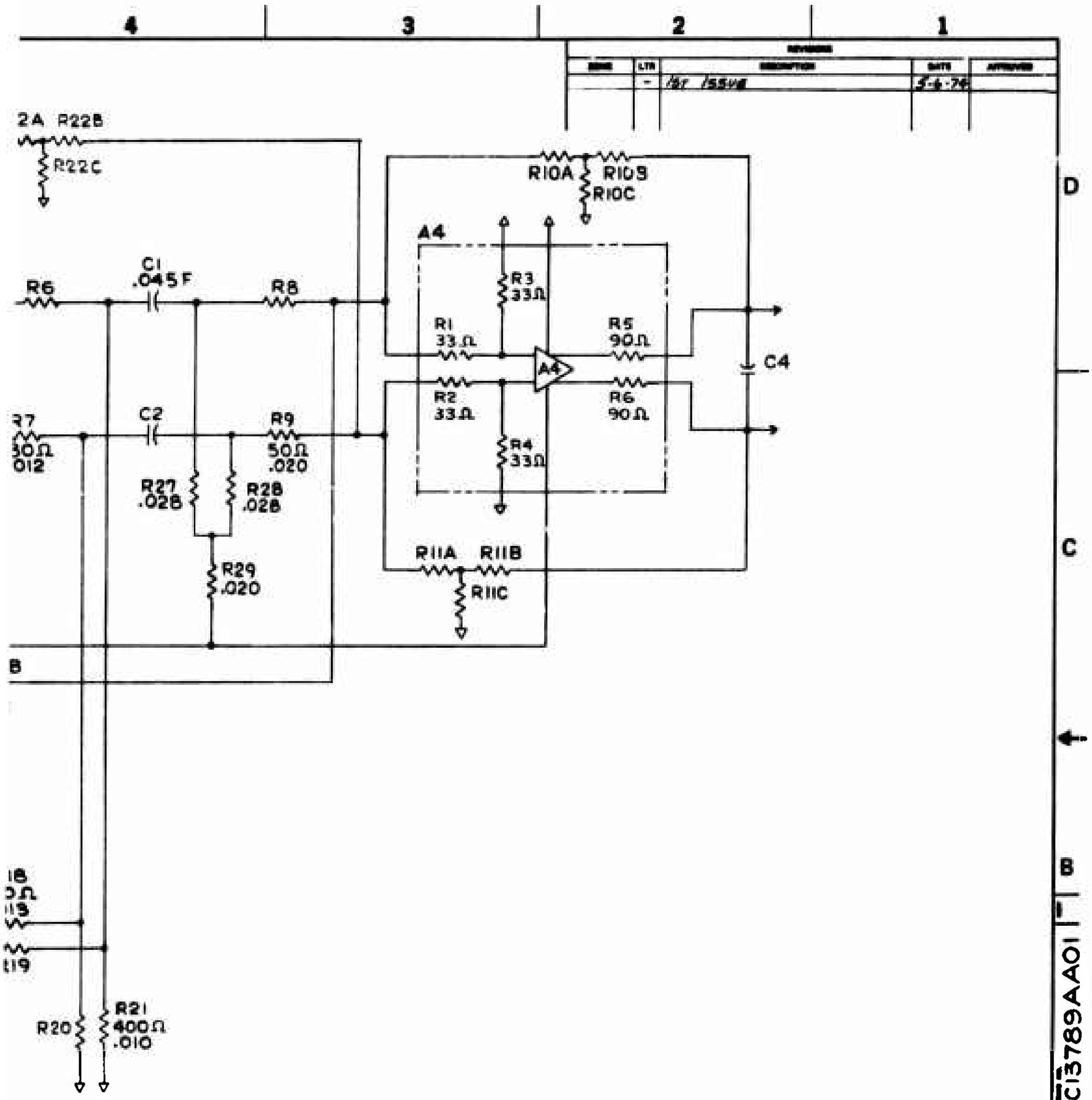

TOLERANCES UNLESS NOTED OTHERWISE

.X ±
.XX ±
.XXX ±

90° FORMED ANGLES +2° -1°

MATERIAL

FINISH—SEE NOTE

YG1158AA01

NEXT ASSY | USED ON

APPLICATION

REFERENCE

DRAFTSMAN Erickson 2-21-74

CHECKER

DEV ENGR

ENGRG MGT

CONTRACT NO.
DAAJ02-73-C-0046

HONEYWELL INC.

GOVERNMENT AND AERONAUTICAL PRODUCTS DIVISION
2600 RIDGWAY PARKWAY
MINNEAPOLIS, MINNESOTA 55413

YAW AXIS-
HYDROFLUIDIC SAS
SCHEMATIC DIAGRAM OF

SIZE	CODE IDENT NO	DRAWING NO.
D	94580	C13789AA01

SCALE | SHEET

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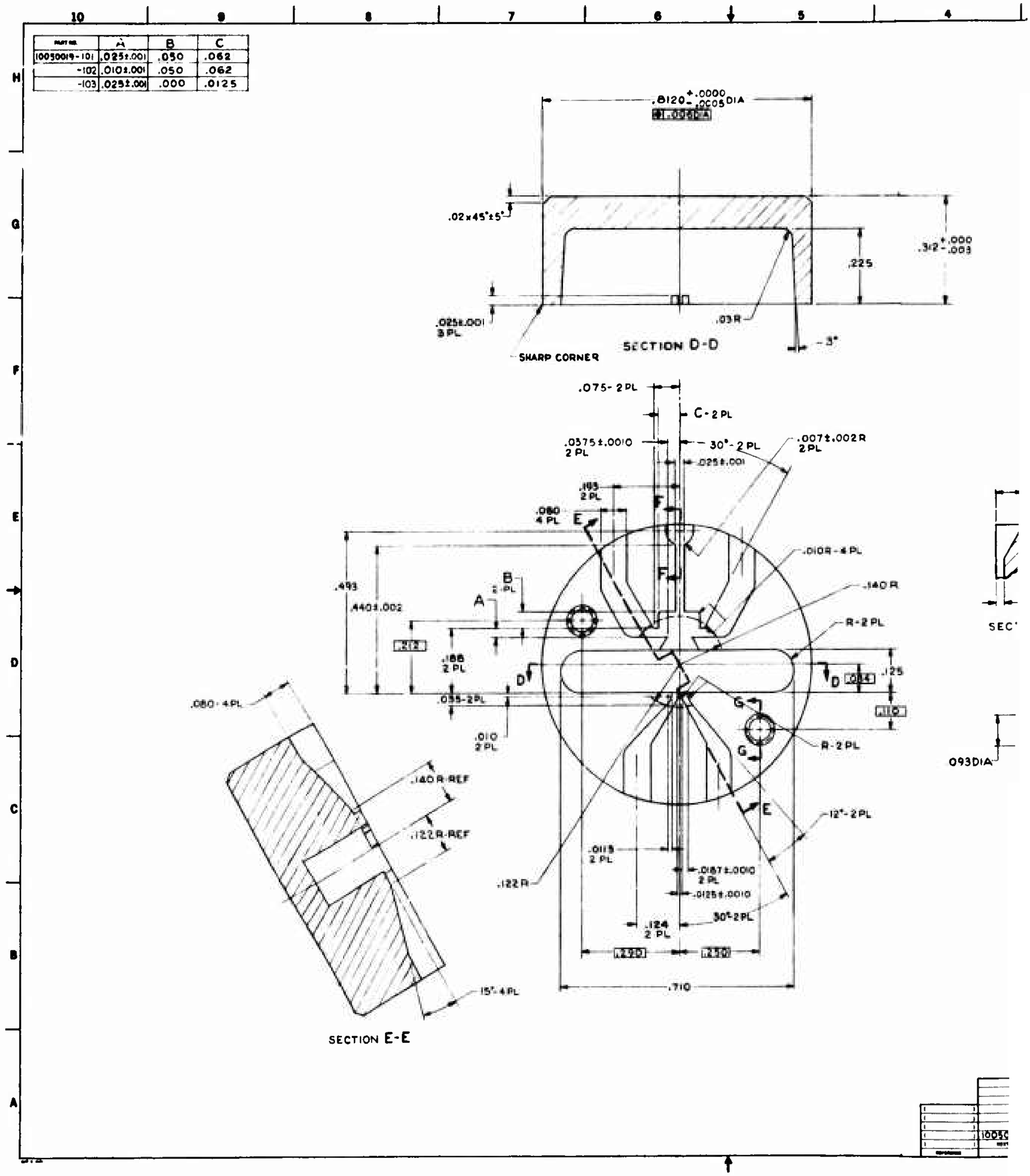

Figure 2. Insert, Amplifier.

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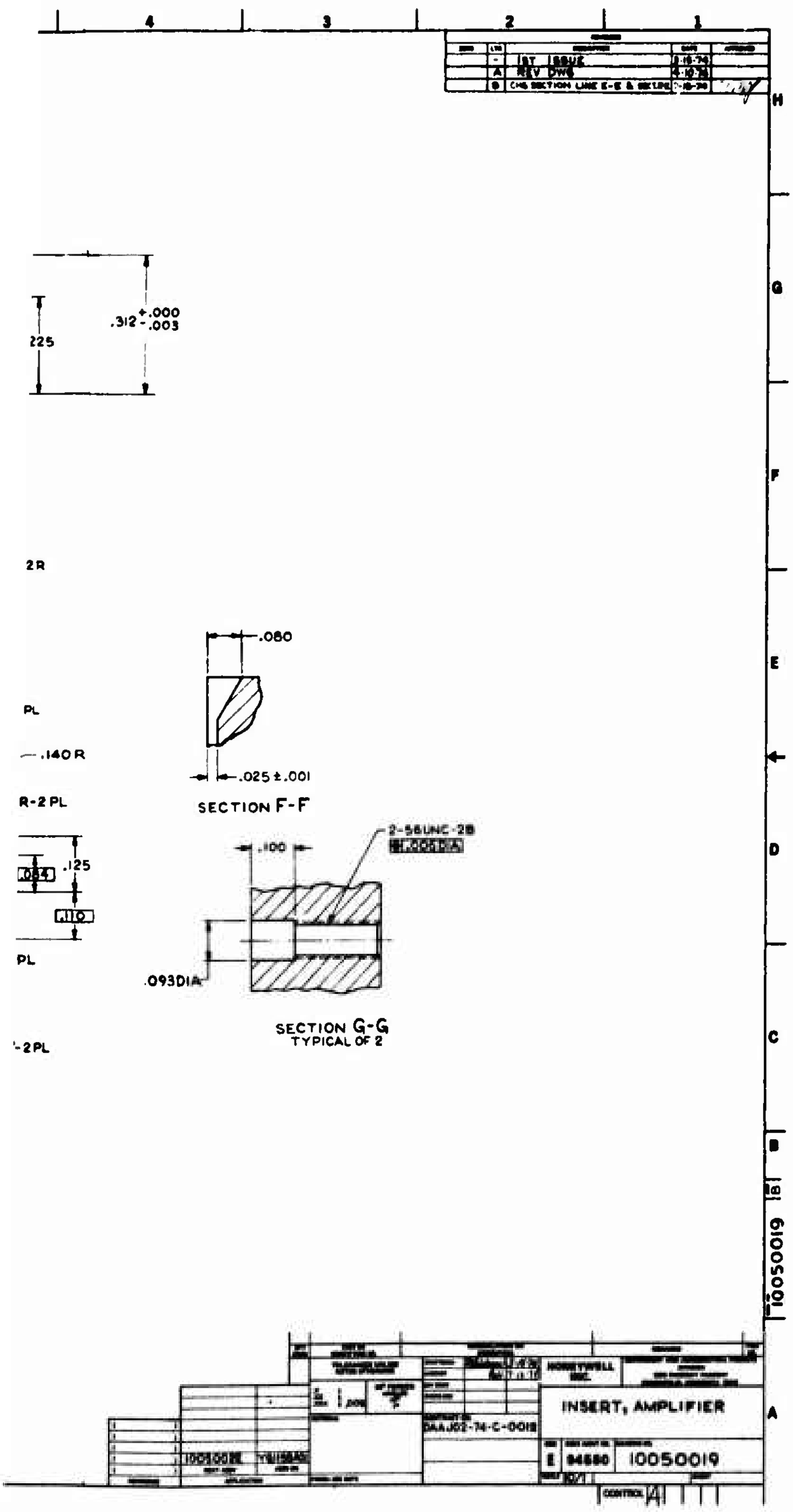

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1
- 1ST ISSUE 3-18-74
A REV DWG 4-10-74
B CHG SECTION LINE E-E & SKETCH 7-18-74
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CONTROL A

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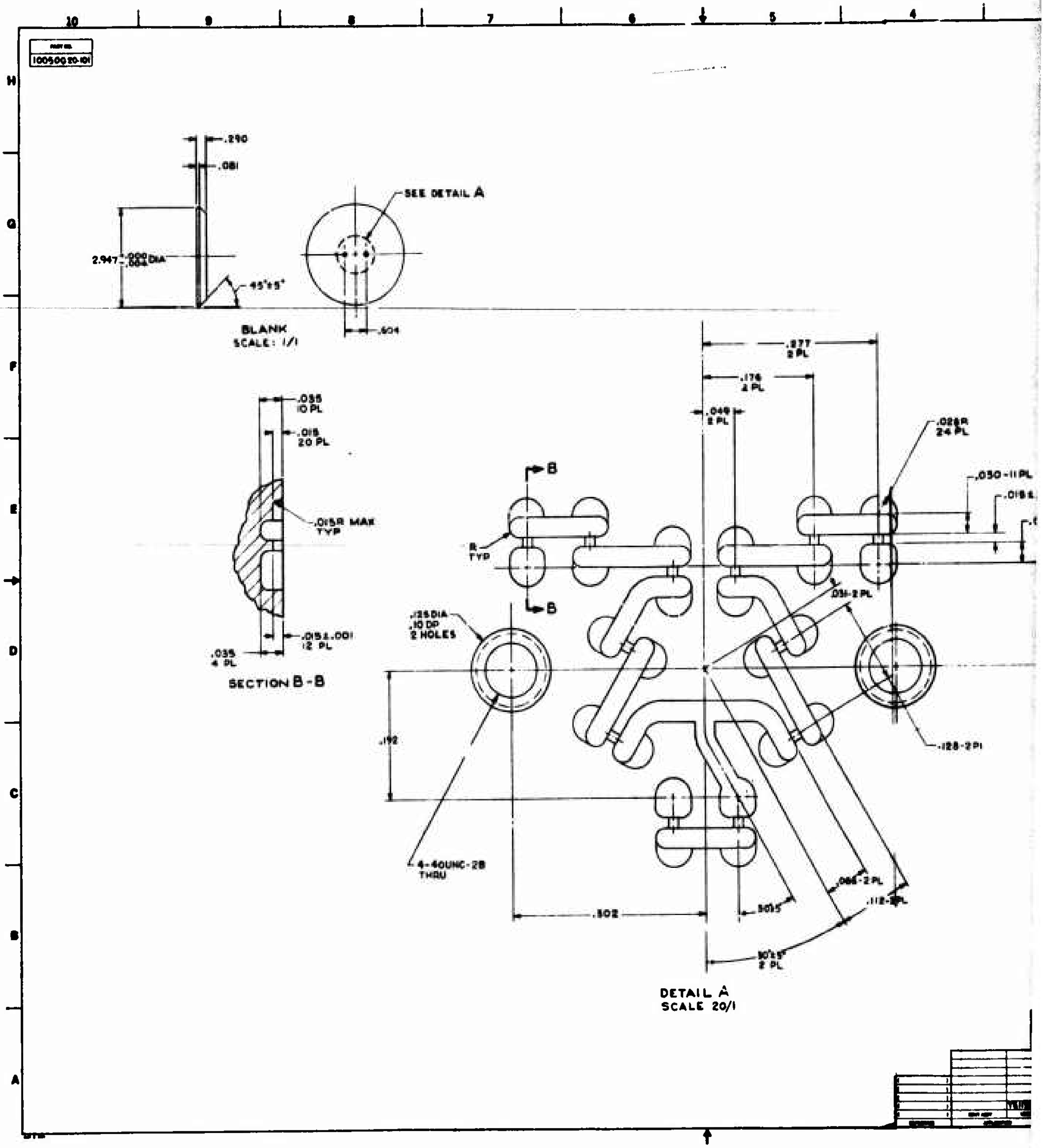

Figure 3. Manifold Resistor.

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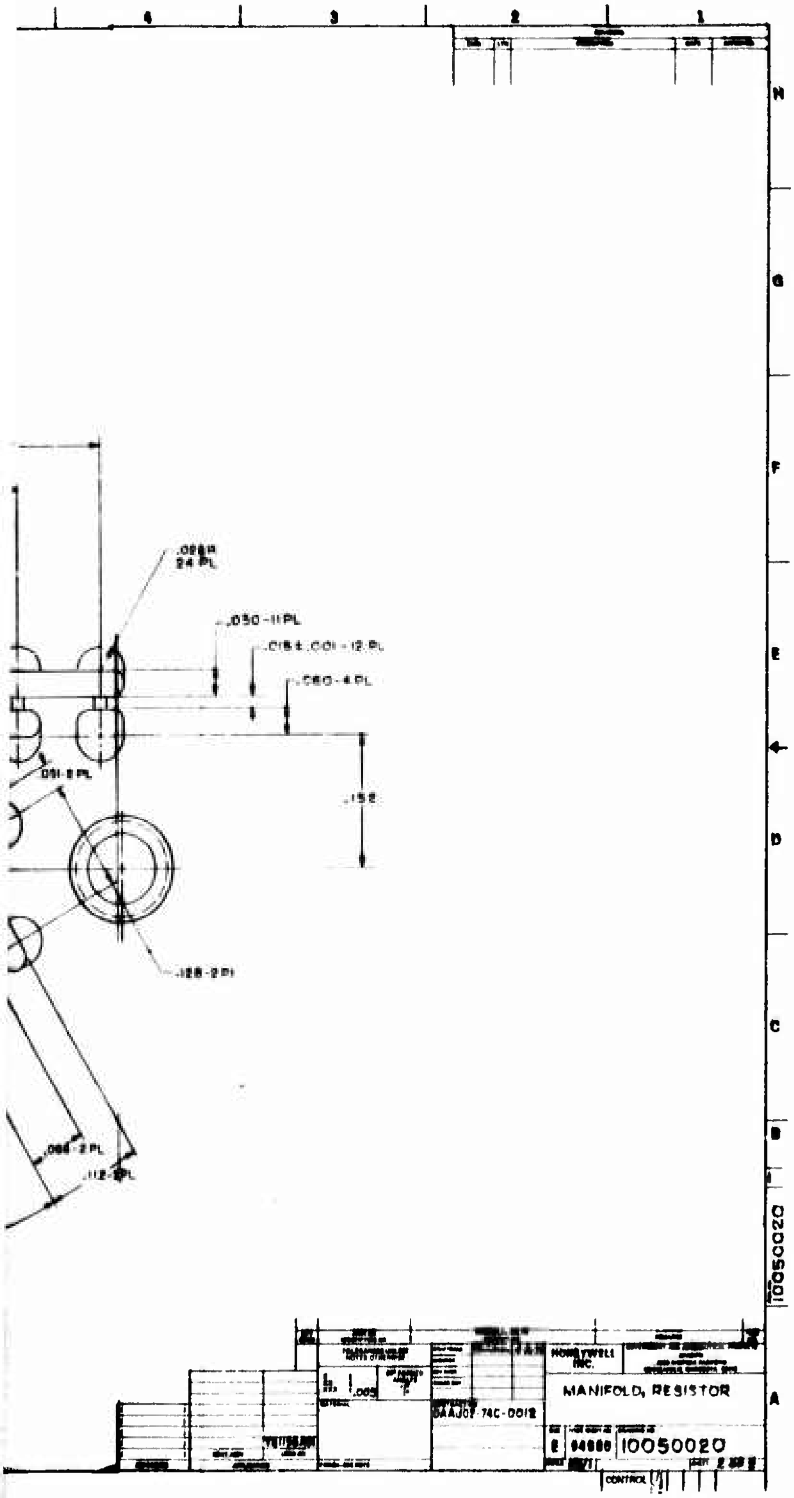

.026R
24 PL
.030-11PL
.0184.001-12 PL
.060-4 PL
.051-2 PL
.152
.128-2 PL
.088-2 PL
.112-2PL
10050020
HONEYWELL INC.
MANIFOLD, RESISTOR
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E
10050020
CONTROL

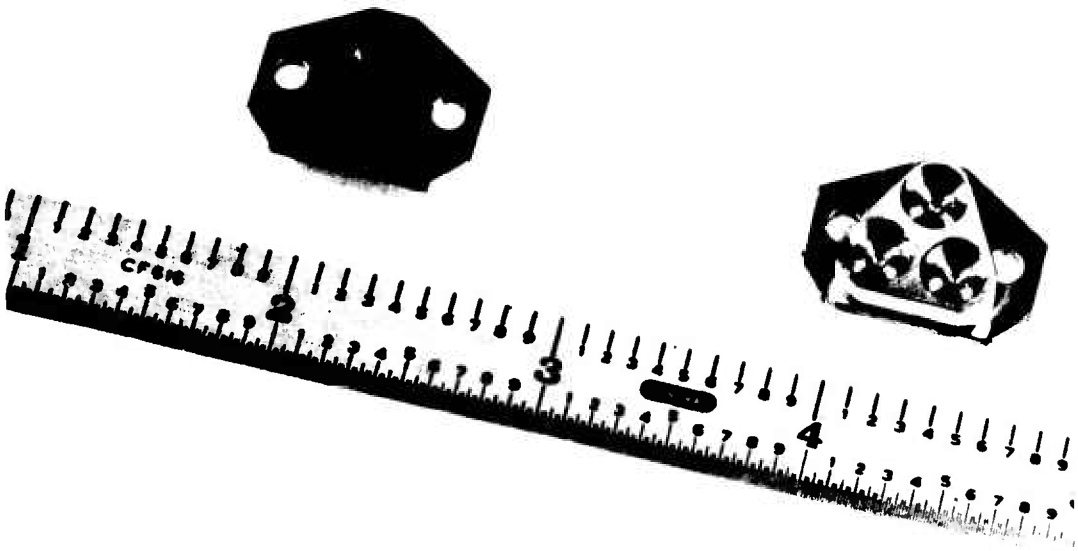


Figure 4. Both Sides of the Resistor Baseplate.

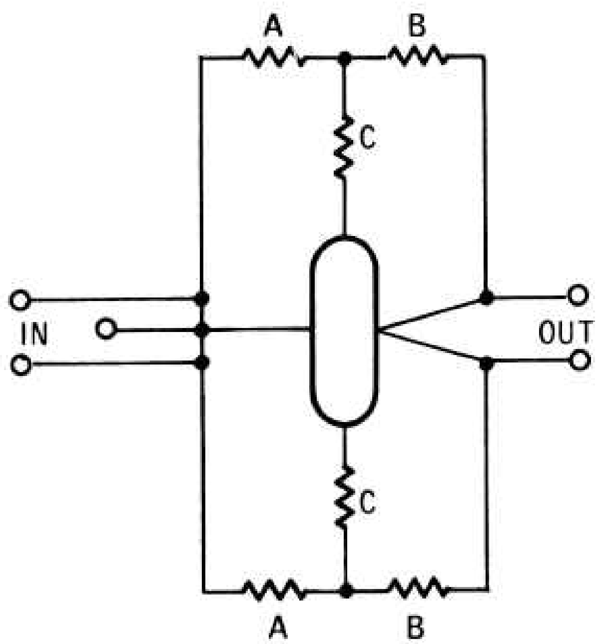


Figure 5. Use of Bridge Resistors as Amplifier Feedback.

where ΔP = pressure drop, lb/in.^{2}

A = area, in.^{2}

R = resistance $\frac{\text{lb-sec}}{\text{in.}^5}$

Resistance of a viscosity-sensitive resistor for rectangular channels is

$$R_\nu = K\nu \tag{2}$$

where

$$K = \frac{1.325 \times 10^{-6} L}{C^3 W \left(\frac{W}{C + W}\right)^2} \tag{3}$$

L = channel length, in.
C = channel height, in.
W = channel width, in.
ν = fluid viscosity, centistokes

Total resistance is the sum of these two effects and is dependent upon both the pressure drop across the resistor and the fluid viscosity. The following calculations define the resistance of one leg of the bridge when the fluid temperature is 120°F (ν = 10cs) and the pressure drop across the leg is 1.0 psid. The leg is made up of five resistors, which are 0.015 inch wide, 0.015 inch high, and 0.015 inch long. Resistance of each element is therefore

$$R_s = \sqrt{\Delta P}/51.6A = \sqrt{0.2}/51.6\,(0.015)^2 = 38.52\Omega \tag{4}$$

$$R_\nu = \nu \frac{1.325 \times 10^{-6} L}{C^3 W \left(\frac{W}{C + W}\right)^2} = \frac{10 \times 1.325 \times 10^{-6} \times 0.015}{(0.015)^3\,(0.015)\left(\frac{0.015}{0.015 + 0.015}\right)^2} = 15.7\Omega \tag{5}$$

Total resistance for five elements in series is

$$R_t = 5(38.52 + 15.7) = 271.1\Omega \quad 54.22\Omega/\text{element} \tag{6}$$

In some cases, R_s is calculated using flow (Q) rather than pressure drop. This equation is

$$R_s = Q/5325\,A^2$$

where A = orifice area, $in.^2$

Q = flow, cis

This second equation for R_S was derived from the definition of point resistance for a sharp-edged orifice, which is

$$R_S = 2\Delta P/Q \tag{8}$$

A mold was fabricated in accordance with Figure 3 with legs A and B having five resistor elements. Leg C used only two elements in series. Five electroformed resistors were tested, and results are presented in Table 1.

TABLE 1. PRESSURE DROP OF RESISTOR LEGS AT Q = 0.021 CIS AND TEMPERATURE = 120°F

Resistor	$\Delta P/Q$ Leg A	$\Delta P/Q$ Leg B	$\Delta P/Q$ Leg C
344	262	255	104
345	261	260	107
346	262	259	105
348	266	258	105
349	259	257	105
Average	262.0	257.8	105.2
Average Resistance per Element	52.4	51.6	52.6

Figure 6 is a schematic of the test setup. Pressure transducers measure the drop across legs B and C when the flow through A is zero. These connections were changed to measure the drop across A and B with no flow in leg C during other tests. Flow was determined by measuring the time required to fill a 100-ml graduate. This is an accurate method for measuring flow in the low-flow range of 0.01 cis. Overall instrumentation accuracy may only be 2- to 3-percent of point.

The data of Table 1 show that the restrictors are consistent to within ±2 percent. This accuracy is better than the projected accuracy of the test equipment; therefore, the true accuracy of the electroformed restrictor fabricated process could be substantially better than ±2 percent. Data of Tables 2 and 3 summarize pressure drop information at several different temperatures and flows. These data are the average of several tests.

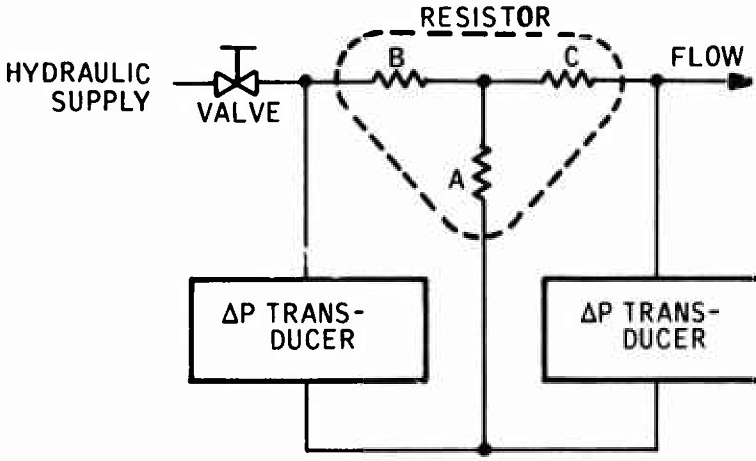


Figure 6. Test Setup for Measuring Flow-Pressure Drop Characteristics of Electroformed Resistors.

TABLE 2. $\Delta P/Q$ AS A FUNCTION OF FLOW FOR TEMPERATURE = 120°F

Q (cis)	$\Delta P/Q$ (Average A&B)	$\Delta P/Q$ per Element
0.0210	256	51.2
0.0137	193	38.6
0.0065	140	28.0

TABLE 3. $\Delta P/Q$ AS A FUNCTION OF TEMPERATURE AND FLOW

Temperature	Q (cis)	$\Delta P/Q(B)$	$\Delta P/Q(C)$	$\Delta P/Q$ Element
140	0.0180	220	91	45.0
140	0.0076	129	58	27.4
76	0.1260	249	105	51.0
76	0.0039	180	80	38.0

Performance at 76°F and 120°F is plotted on Figure 7. The curves are extended to show the value of $\Delta P/Q$ that would exist at zero flow where the resistance of a sharp-edged orifice is zero. Resistance is 18.3Ω at 120°F and 31.8Ω at 76°F. New 5606 oil has a viscosity of 10 centistokes at 76°F. Resistance of a linear restrictor was previously defined as $R_V = K\nu$. K, as determined by test results, is 1.77 at 76°F and 1.83 at 120°F. The calculated value of K was 1.57, representing good correlation with the above test data.

Increase in $\Delta P/Q$ with respect to flow is a result of the sharp-edged orifice component. At 120°F, a flow increase of 0.02 cis increased $\Delta P/Q$ by about 30.2; therefore,

$$R_s = \frac{2\Delta P}{Q} = 60.4\Omega \text{ at } Q = 0.02 \tag{9}$$

also $$R_s = \frac{Q}{5325A^2} = 3,708\,Q \text{ for } 0.015 \times 0.015 = 74\Omega \tag{10}$$

The design value of R_s was 74Ω as compared to the tested value of 60.4Ω at this flow condition. Slope of the 76°F line is parallel, indicating the same R_s characteristic.

Performing the calculations and plotting the graphs using the 140°F data emphasizes the fact that a small shift in drawing the slope through the data points can result in a substantial change in calculated constraints. In some cases, a 1-percent error in the measurement of $\Delta P/Q$ for one data point could result in a 5-percent or 10-percent error in the computation of R_s.

Other resistors were fabricated with a different number of elements in each leg to provide flexibility in the development of the integrated circuit.

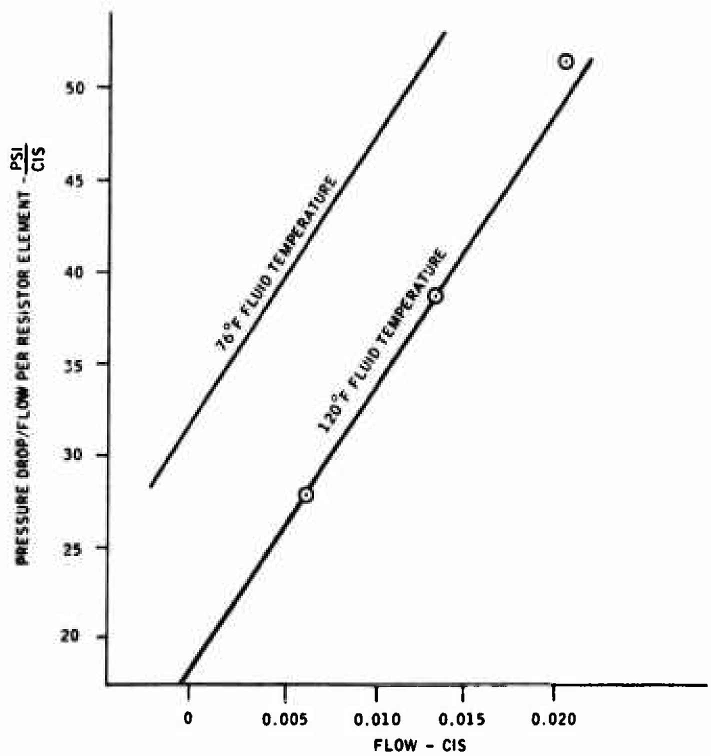


Figure 7. Resistor Pressure Drop/Flow Versus Flow Characteristics.

Nearly all resistor problems were associated with the -4 "O"-ring seals at the bottom of the resistor baseplate. Early in the testing it was discovered that the "O"-ring squeeze was sufficient to completely block the passageway under some conditions. Metal tubing (0.094 inch diameter) was cut into 0.050-inch lengths and was used as backup rings as a temporary fix. A substantial amount of "O"-ring damage resulted from the excessive compression, and contamination was generated from these seals during development testing. Production units will incorporate a permanent fix. The resistor baseplate "O"-ring grooves will be enlarged and -5 "O"-rings will be used.

Only one resistor mold was fabricated during this development phase, but many different resistor configurations were electroformed. This was accomplished after the wax was injected onto the baseplate by manually adding small amounts of wax to the unwanted elements. Using this technique, a leg with five elements could have its resistance accurately reduced in increments of one element. Pairs of resistors were made in six different combinations to provide flexibility for development testing.

Development results on electroformed resistors were excellent. Only a few formulas are required to design a resistor with any linear resistor plus orifice restrictor characteristic. Changes in oil viscosity with use is the largest uncontrolled variable, and it reduces the accuracy of parametric test data on viscosity-sensitive restrictors. Complete systems can tolerate large changes in viscosity, as these effects are largely cancelled by equivalent changes in matching restrictors.

INTEGRATED CIRCUIT (I/C) HARDWARE DESIGN

Control systems fabricated under this producibility program are required to be interchangeable with the YG1143 systems developed under Contract DAAJ02-73-C-0046. The major difference between this YG1158 system and the previous YG1143 system is that the amplifiers and manifolds are electroformed into a single integral unit. By definition, this precludes the use of adjustable resistor blocks mounted between the amplifiers and the manifold. As many of the previous components were retained with the new design as was practical. Rate sensor internal hardware, pilot input device, and flow control were among the components that remain unchanged.

One of the program objectives was to design a single integrated amplifier-manifold circuit to replace the upper and lower manifold assemblies of the previous program. To accomplish this it was necessary to minimize the size of the interconnecting lines. The nominal cross section of the interconnecting lines was selected to be 0.080 inch by 0.080 inch. Using the formulas presented in the resistor design sections of this report, the viscosity-sensitive resistance of these lines is

$$R_{\upsilon} = \upsilon\, 0.13\ \Omega/\text{inch} \tag{12}$$

where R_{υ} = resistance, hydraulic ohms.

Equivalent, sharp-edged orifice resistance of these lines is 0.64Ω, when the flow is 0.14 in.^{3}/sec. Total resistance for a 2-inch length of channel at a flow of 0.14 in.^{3}/sec and at a temperature of 120°F is about 3.2Ω as compared to 67 ohms for a power nozzle, and 30 to 300 ohms for control ports.

A layout drawing was made to determine the feasibility of compacting all of the required amplifiers and interconnects onto a single plate without exceeding envelope requirements while keeping the lines in the right location to mate with the required rate sensor output, capacitors, etc.

Results of this design effort were converted into the detailed design drawings of Figures 8 and 9. The developmental circuit used separate standoffs to interface between the integrated circuit and the housing. Production units will use electroformed standoffs, simplifying assembly and reducing the number of required "O"-ring seals.

The housing, shown in Figure 10, is almost identical to the YG1143 design except for some hole location changes made to accommodate the integrated circuit configuration.

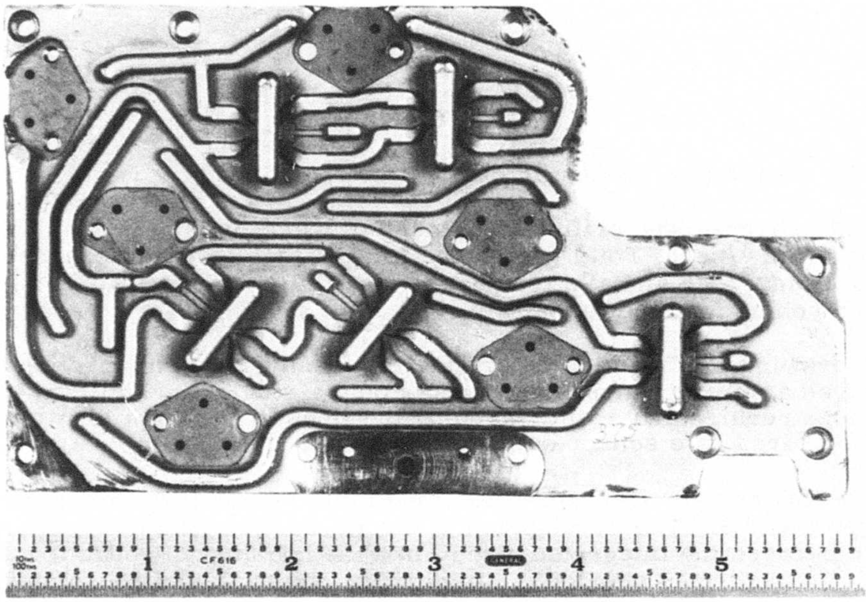


Figure 8. Integrated Circuit - Top View.

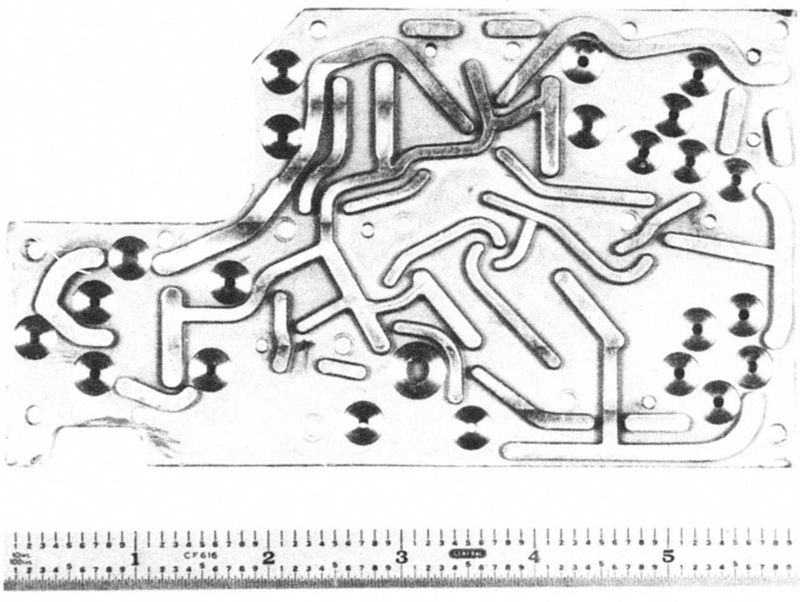


Figure 9. Integrated Circuit - Bottom View.

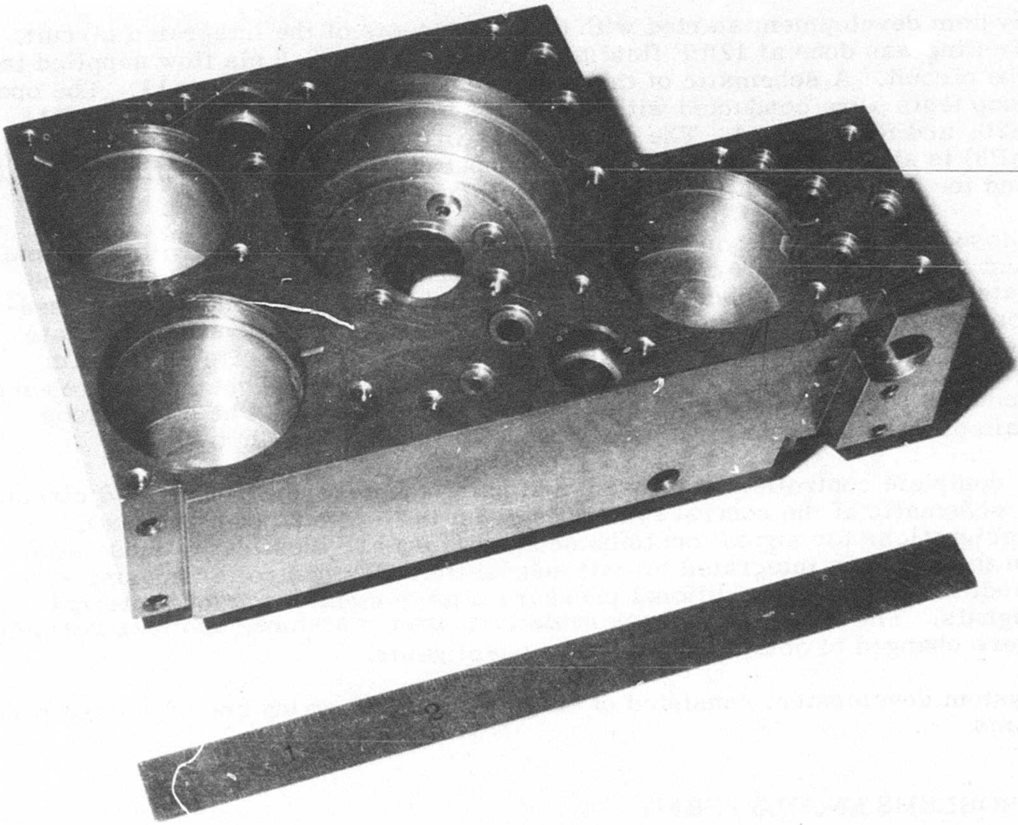


Figure 10. Photo of Housing.

SECTION III
SYSTEM DEVELOPMENT

DEVELOPMENT SEQUENCE

System development started with open-loop tests of the integrated circuit. Testing was done at 120°F fluid temperature with a 0.8 cis flow supplied to the circuit. A schematic of this test setup is shown in Figure 11. The open-loop tests were conducted with restrictors R3, R26, R22, R23, R10, R11, R20, and R21 blocked. The open-loop gain of the rate sensor circuit ($\Delta P2$ to $\Delta P3$) is shown in Figure 12, the pilot input circuit ($\Delta P7$ to $\Delta P3$) in Figure 13, and the driver circuit ($\Delta P4$ to $\Delta P6$) in Figure 14.

Closed-loop test data on the integrated circuit was obtained with the same test setup, but the previously blocked restrictors were connected and the rate sensor output impedance was simulated. Figure 15 shows the closed-loop gain of the rate sensor circuit ($\Delta P1$ to $\Delta P3$) using the simulated rate sensor output impedance. Figure 16 shows the through-rate signal gain ($\Delta P1$ to $\Delta P6$) from the rate sensor to the final output. This gain represents about 15 percent of the total high-passed output signal. The closed-loop gain of the pilot input circuit ($\Delta P7$ to $\Delta P3$) is shown in Figure 17.

A complete controller was assembled using the described integrated circuit. A schematic of the control system is given in Figure 28 of Appendix C. Designations for signal locations and resistors are identical to those used on the previous integrated circuit schematic. The controller housing was modified to provide additional pressure taps to monitor various internal signals. The sizes of feedback resistors, load resistors, and bias resistors were changed to obtain the desired system gains.

System development consisted of obtaining suitable gains and of solving problems.

PROBLEMS ENCOUNTERED

Feedback Resistor "O"-Rings -- Problems of signal blockage and of generation of contamination associated with the use of -004 size "O"-rings were discussed in the feedback restrictor design section of this report. Use of larger -005 "O"-rings is expected to eliminate these problems.

Standoffs -- Developmental hardware used two "O"-rings and a replaceable mechanical standoff for each fluid connection between the integrated circuit and the housing assembly. This configuration was difficult to assemble. At times, the mechanical standoffs would cock, preventing a good seal and,

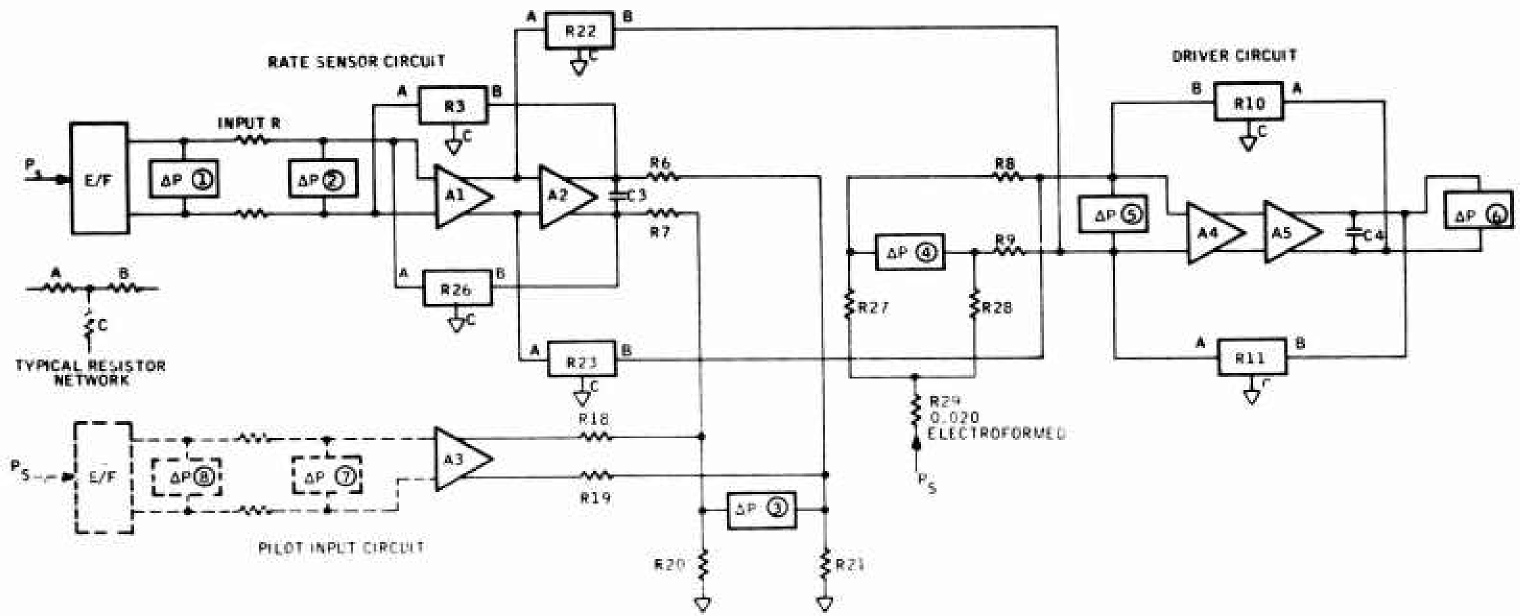


Figure 11. Integrated Amplifier Circuit Test Setup.

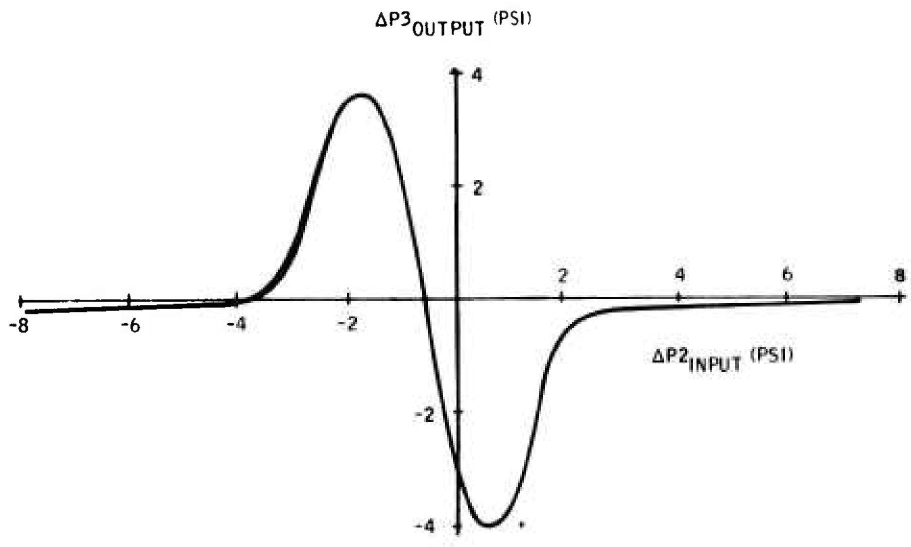


Figure 12. Rate Sensor Circuit Open Loop-Gain.

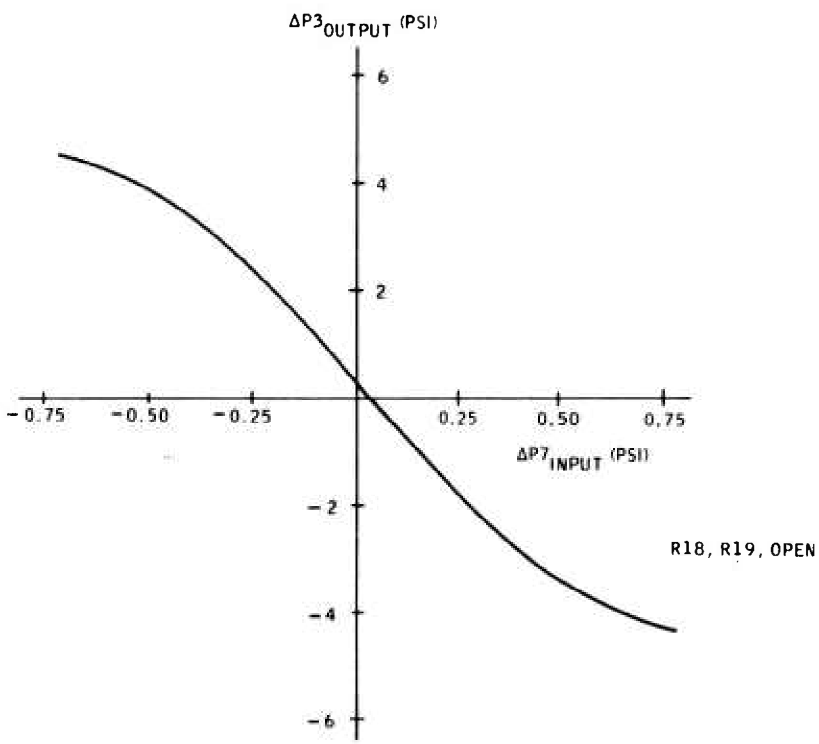


Figure 13. Pedal Input Circuit Open-Loop Gain.

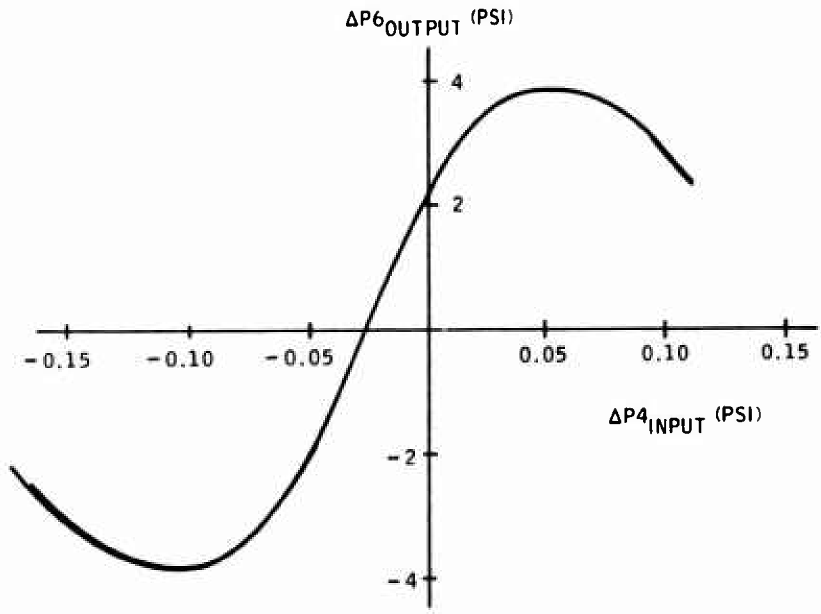


Figure 14. Driver Circuit Open-Loop Gain.

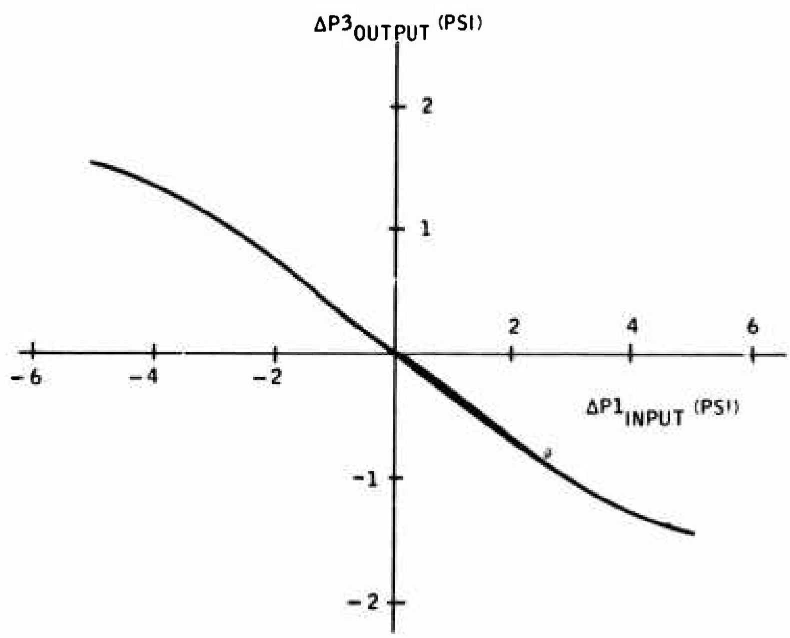


Figure 15. Rate Sensor Circuit Closed-Loop Gain.

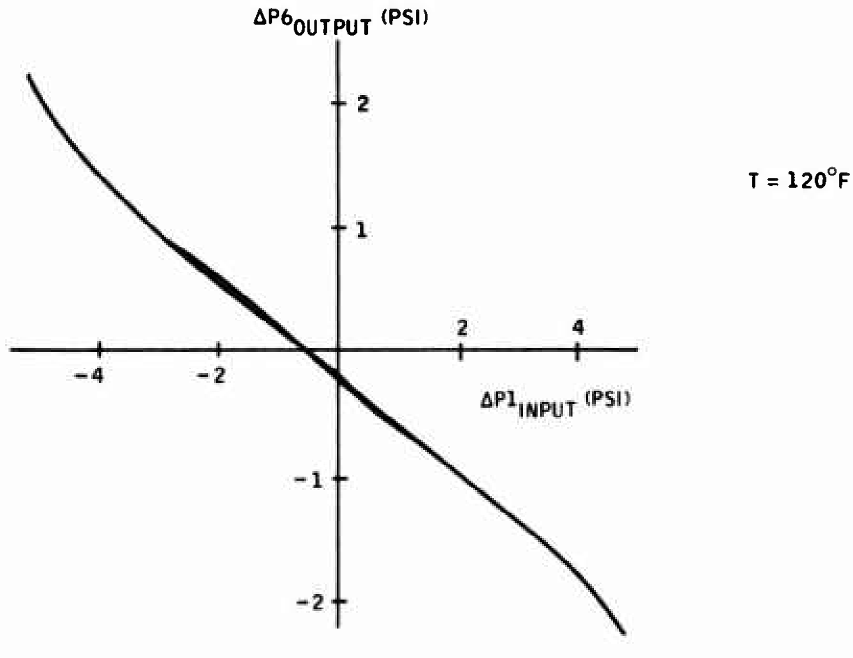


Figure 16. Rate Sensor Through-Rate Gain.

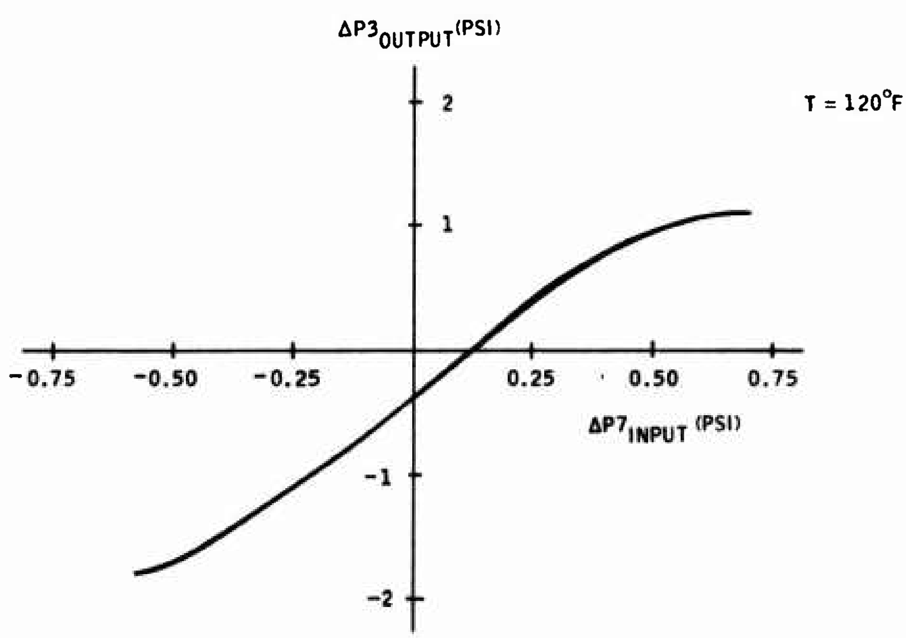


Figure 17. Pedal Input Circuit Closed-Loop Gain.

therefore, would require reassembly. Production units will use integral electroformed standoffs which require only one "O" - ring and which will eliminate the misalignment problem. Present experience with electroformed standoffs on other programs indicates that they do not affect system performance.

Rate Sensor Pickoff -- Rate sensor null offset of 30 degrees per second or more was a significant problem. A restriction or bias can be introduced to compensate this offset at one temperature; however, the offset usually changes as a function of fluid temperature, and matching the compensation over the operating temperature range is difficult. Reducing rate sensor null offset also reduces the amount of null shift with temperature. A rate sensor pickoff was fabricated with four pickoff ports, and it demonstrated substantially better performance than the previous two-port configuration. The improvement seems to be a result of shorting out any pressure difference existing across the rate sensor sink due to misalignment. Also, the output impedance of the pickoff is substantially reduced.

Pilot Input Device -- The pilot input device (PID) consists of a sleeve, spool, and associated linkage. Installation of the sleeve into the controller housing was designed to be accomplished by a press fit. Leakage was a major problem with this configuration; and a press fit and a shrink fit did not give a leak-tight configuration even when the sleeve was lightly plated to increase the interference. This problem was solved by incorporating radial grooves around the outside of the sleeve at each end and by using epoxy to provide an oil-tight seal.

During qualification tests, the PID output experienced a large null shift, which was found to be caused by a mechanical slippage. The fork and operating shaft were pinned together to prevent reoccurrence of this problem. Appendix C, Development and Evaluation Lab Engineering Test Report. Paragraph 4. 3 explains the problem in more detail.

Removal of Wax from Electroformed Circuits -- Removal of conductive wax from electroformed components had been a problem in previous programs. In this producibility program, hot solvent (above the melting point of the wax) was pumped through the circuit and/or components. There were no indications of residual wax in any components during the development program.

Nonlinear Bellows -- Specifications for fluidic capacitors require that they be linear within ±20 percent over a range of ±2 psid. Bellows procured to this requirement were found to have the characteristics shown in Figure 18. These bellows do have a linear range, but it is necessary to bias the fluidic circuit to ensure that the bellows operate in compression by an amount equal to 2 psid. This compromise did make development more difficult. Electroformed linear (about centers) bellows have been ordered for later phases of this program.

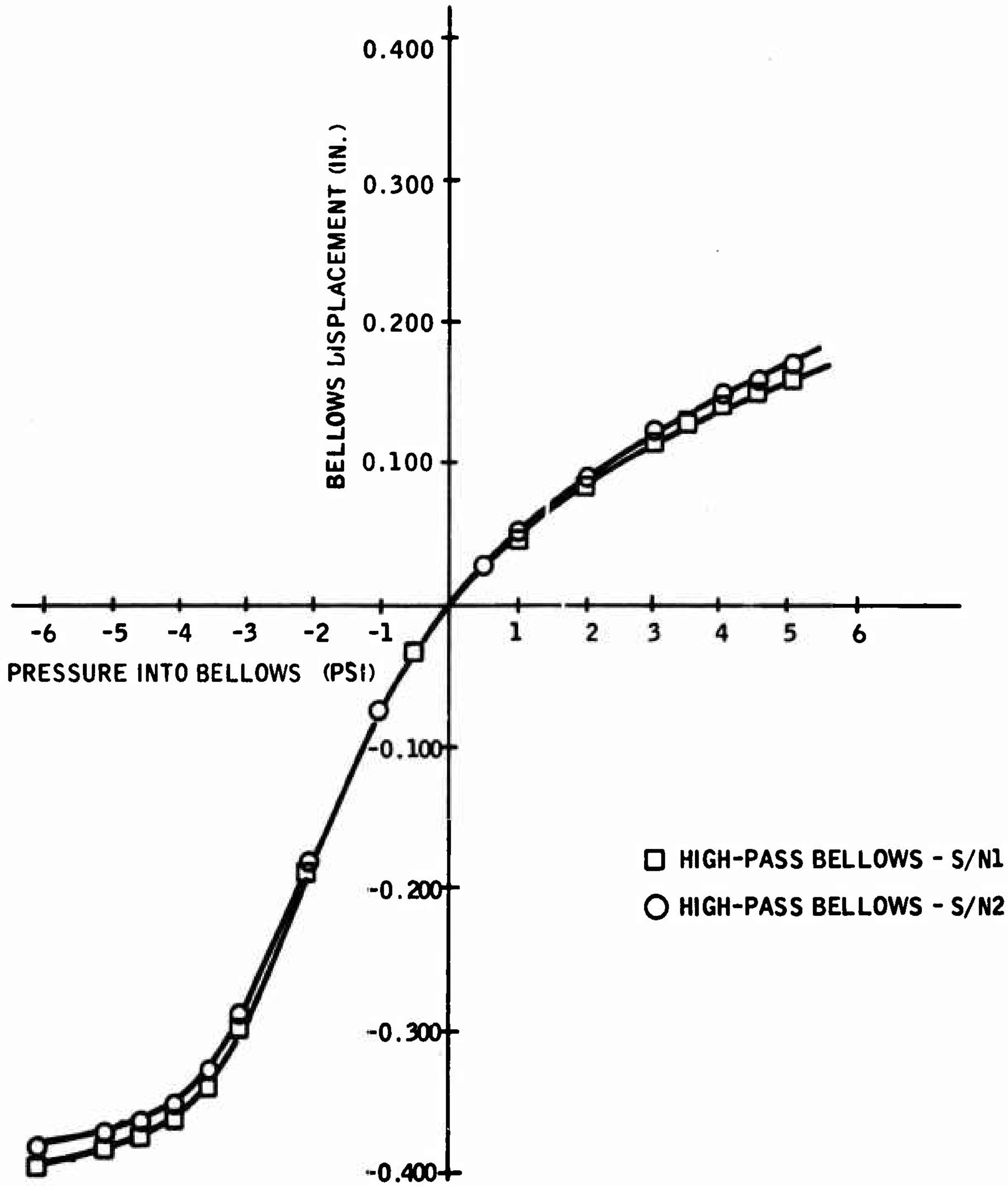


Figure 18. High-Pass Bellows - Pressure Versus Displacement.

Electroformed Manifold Design Problems -- Two views of the integrated circuit are shown in Figures 19 and 20. Amplifiers shown on the top view are the rate sensor cascade (two amplifiers), the output driver cascade (two amplifiers), and the PID amplifier. Bridge-type resistors use return pressure as a ground reference, and pressure drops in the return manifold result in a slightly different pressure between the two reference ports for the rate sensor cascade feedback resistors. If space permitted, the ideal configuration would be for these two ports to be joined together before they connect to the return manifold. A null offset of about 0.5 psid in the output of the rate sensor cascade resulted from this differential. This offset is almost within acceptable limits; however, mismatched feedback resistors were needed to eliminate most of this effect. Present plans call for elimination of feedback on the rate sensor cascade in later phases of this program, and therefore this problem will not exist.

Summing -- Signals are summed together in several locations on the integrated circuit. Resistance of a sharp-edged orifice is directly proportional to the differential pressure across it, and at zero ΔP, it has zero resistance; therefore, characteristics of summing junctions vary substantially when the input signal levels change. The most difficult area is the summing junction between the rate sensor cascade and the PID amplifier. For example, when PID is displaced to its extreme, the pressure downstream of R7 (Figure 1) increases by 0.5 psi and the pressure downstream of R6 (Figure 1) decreases by 0.5 psi. During development testing, the pressure drop across R7 (Figure 1) decreased to zero under these conditions, causing a substantial change in the rate loop gain characteristics. Increasing the physical size of R20 and R21 (Figure 1) reduces the pressure downstream of all summing resistors and minimizes the change in resistance with signal level. This solution can be implemented more easily with linear capacitors, as it is not necessary to maintain a bias upstream to maintain linear capacitance. Changes in these bias levels can also increase or decrease the input impedance to the high-pass capacitors, thereby changing high-pass time constant.

Range -- It is important to maintain sufficient range in all areas of the circuit under normal operation. Under high-temperature conditions, the amplifier ranges decrease; therefore, obtaining a full ±2-psid range at the output of the driver cascade is difficult. Supply pressure can be increased, but this also increases system noise. Because most of the system noise comes from preamplifier stages, it is desirable to operate the preamplifier stages at a low pressure for minimum noise and the output amplifier at high pressure for increased range. The present circuit configuration is not capable of operating in this manner, but the circuit will be modified in production units to provide a higher supply for the output stage.

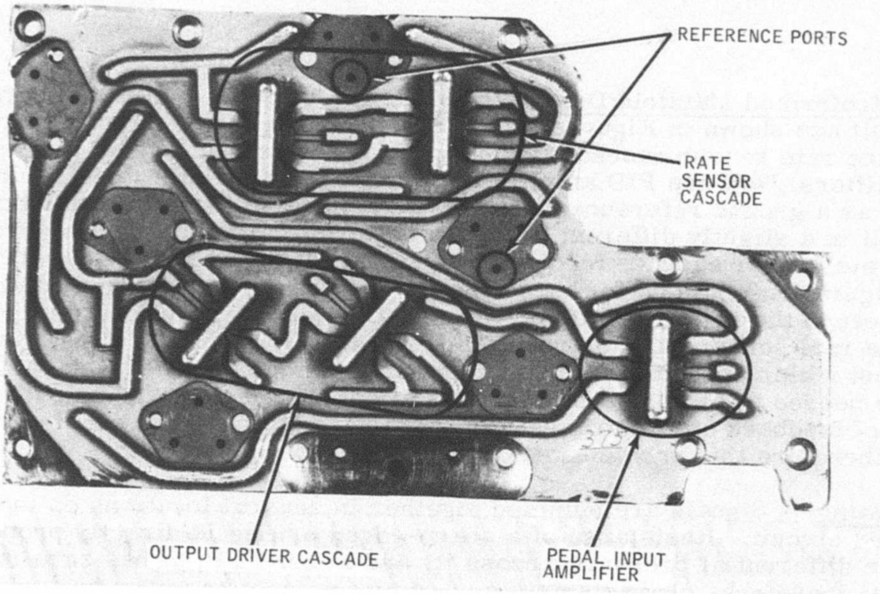


Figure 19. Integrated Circuit - Top View.

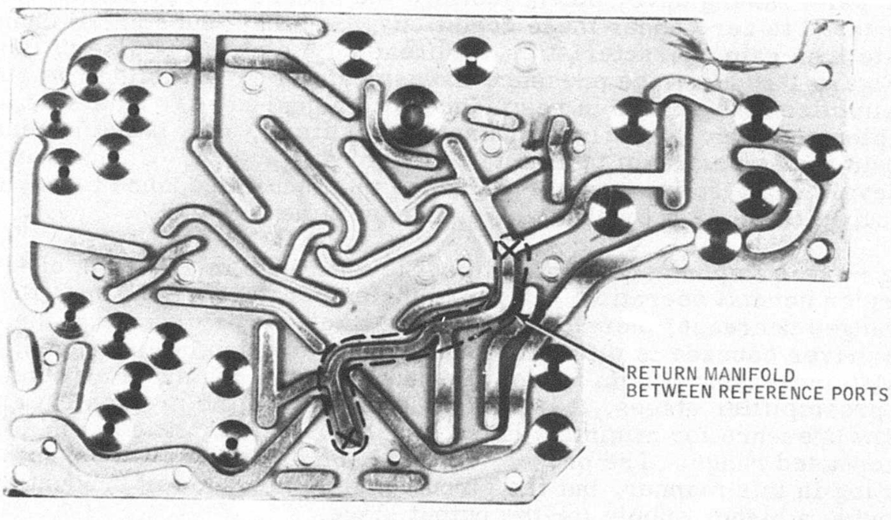


Figure 20. Integrated Circuit - Bottom View.

Noise -- Noise is the biggest problem associated with the design of fluidic flight control systems. Many of the rate sensor and amplifier design changes are directed to reduce system noise. Noise can also be reduced by improved manifolding techniques and by operating amplifiers at a lower supply pressure. Some of these changes introduce new problems of reduced range or of gain changes as a function of fluid temperature. A discussion of modifications introduced in this program to reduce system noise follows.

A four-port pickoff provides a higher-loaded scale factor requiring less preamplification, thereby reducing noise. Four ports in place of two also provides some cancellation of pickoff-generated noise. Use of a four-port pickoff did not result in a substantial noise improvement during the development phase, however, because of other noise generation.

High-frequency noise in excess of 100 Hz cannot be detected by the X-Y plotters used in development testing. A brief investigation was conducted using an oscilliscope to isolate the causes of this noise. It is suspected that the lag capacitors are in a configuration that does not properly attenuate this high-frequency noise. Much of it appears to be associated with the rate sensor cascade and its feedback. Eliminating the preamplifier feedback would substantially reduce this noise. The servoactuator will not respond to the high-frequency noise, but it does have other detrimental effects: it can induce subharmonics, drive later stages into saturation, and induce turbulent flow into the final stages.

Output manifold noise can reflect throughout the system. In the original system configuration, the rate sensor return flow passed through the integrated circuit manifold (return channel), generating an intolerable level of system noise. The rate sensor return port was moved to the bottom rate sensor cover (separate from integrated circuit return), eliminating this source of noise.

Power-supply orifices have generated noise in previous systems. A screen was placed downstream of the power-supply restrictor to the integrated circuit (Figure C-1 of Appendix C) to reduce system noise, but it also reduced amplifier supply pressure. When the supply pressure was increased, the noise returned to its original level. Test results indicate that noise generated from the power supply restrictor in the manifold is insignificant, but small orifices located close to an amplifier power inlet generate excessive noise.

Gain change as a function of temperature was found to be greater than desired for a typical stability augmentation application. This characteristic can be improved by optimizing the relative supply pressure to each stage and by reducing the number of amplifiers. The developmental integrated circuit did not have provisions for making those changes; however, experience on the operational suitability program (Contract DAA J02-73-C-0046) has demonstrated a satisfactory gain versus temperature characteristic.

Changes in the production phases of this program are expected to demonstrate an equivalent improvement.

Based on the discussed developmental problems, the following changes will be made:

- Use a four-port rate sensor pickoff
- Eliminate the feedback on the rate sensor cascade
- Use linear (over center) high-pass bellows
- Operate preamplifier stages at a lower pressure
- Pin the PID linkage fork to its shaft
- Place the system return on the rate sensor bottom cover rather than on the integrated circuit output
- Use electroformed standoffs on the integrated circuit
- Use -005 "O"-rings on electroformed resistors

Implementation of these changes should result in a system with performance superior to that now being flight tested in the Operational Suitability program.

SECTION IV

QUALIFICATION TEST

Qualification tests were conducted in accordance with the Environmental Test Plan given in Appendix A. System performance requirements are defined in detailed specification DS24470-01, given as Appendix B. Honeywell requested and received approval (reference contract modification P00002) to conduct these tests without an actuator, as AMRDL was unable to supply a unit as required in the contract. Consequently, the test results are presented in units of psi/deg/sec instead of inches of servo/deg/sec. To convert the test results into units compatible with the detailed specification, the test results should be multiplied by the servoactuator scale factor of 0.15 inch/psi. The Development and Evaluation Laboratory Test Report describing the qualification test is given as Appendix C. The report is complete; only a few observations will be noted in this section.

It should be noted that the oil viscosity after use at 120°F was equivalent to new oil at 143°F, and viscosity at 180°F was equivalent to new oil at 210°F. Operation over a temperature range from 90°F to 150°F, which is equivalent to a range from 110°F to 180°F with new oil, is compatible with requirements for an OH-58 helicopter. Noise at 150°F (180°F new oil) is slightly high but would be reduced if an actuator were used. Gain and response variations of the rate and PID loop over the range of 46°F to 180°F are shown in Figures C-3 and C-5 of Appendix C. Gain remained relatively constant for amplitudes from ±2°/sec to ±15°/sec, indicating good linearity, minimum hysteresis, and very little saturation (reference Table C-1, Appendix C).

SECTION V

PILOT PRODUCTION LINE DESIGN

BACKGROUND

The ECW process has previously been used successfully in a highly controlled laboratory environment for the fabrication of fluidic components for various developmental fluidic programs. One goal of the ECW producibility program is to determine if this process can be used in a production environment operated by production personnel. This objective also includes the requirement that the hardware be tested against written performance requirements on certified test equipment, and that the hardware meet these requirements.

To meet this goal, a pilot production line was designed. This line includes the following major items:

- Equipment needed to inject and plate the required piece parts
- Equipment needed to test the required piece parts

EQUIPMENT NEEDED FOR INJECTION AND PLATING

The process used to produce acceptable fluidic hardware by the ECW process can be broken down into three major areas:

- Wax formulation
- Wax injection
- Nickel plating, cleaning and machining

Wax Formulation -- The formulation of this wax requires the use of standard equipment only; no special-purpose tooling has been ordered.

Wax Injection -- Wax injection is a delicate process. Care must be taken such that when the baseplate and mold are separated, the wax will adhere to the baseplate and not to the mold. This problem, called lifted-wax mandrels, is a function of mold design, baseplate cleanliness, and injection pressure settings. If the wax mandrel lifts slightly, the plating solution will wick under, causing the part to raise up. Because the bottom of the manifold is ground flush for mounting purposes, this raising of the mandrel results in a thin-plated area. The other problem created by the wax mandrel adhering to the mold is wax cracking. Any crack in the wax form will cause the plating solution to form a curtain across the affected passage area. Such a failure is very hard to discover and impossible to repair. It must be prevented or discovered before plating has started. At the present time, every wax form (mandrel) will be visually inspected for these two failures by using a microscope. It is anticipated that this inspection can be discontinued after additional experience is gained in wax injection.

The injection of the wax onto a suitable baseplate requires an ultrasonic cleaner, a vacuum pump, an abrasive blast facility, an injection molder of suitable capacity, and a source of heating water. The pieces of special-purpose tooling that have been ordered are listed in Table 4.

TABLE 4. SPECIAL-PURPOSE TOOLING REQUIRED FOR WAX INJECTION

Tool Part Number	Name	Quantity
YG1158T15	Ultrasonic Cleaner	1
YG1158T19	Injection Molder	1

Using this equipment in conjunction with existing facilities will allow us to inject wax on the three types of baseplates used for the producibility programs.

Nickel Plating -- Once the wax mandrel has been injected onto the baseplate, the whole assembly must be plated with a Barret Sulfamate Nickel plating. The plating process itself consists of H_2SO_4 cleaning, a Wood's Nickel Strike, a deionized water wash, and the actual plating for a long period of time. It takes only a few minutes to complete the first three steps of the plating process, but the final step is done very slowly to minimize the amount of nickel buildup on the edge of the part. The total process takes approximately two days. After the plating is finished, the part must be inspected under magnification to ensure proper plating. Some of the parts, such as the rate sensor and integrated circuit, will require a small amount of machining to clean up the mounting areas. Once this step is complete, the part is mounted on the flushing pump. This removes any trace of the wax mandrel. The part is then ready to test.

Each part requires a special fixture to hold it once it has been injected with the wax. These fixtures are listed in Table 5, and drawings of them are shown in Appendix D. These fixtures are based on previous designs with the improvements required to make them suitable for a production environment.

TABLE 5. REQUIRED PLATING RACKS		
Tool Part Number	Tool Name	Used Piece Parts
YG1158-T16	VRS Plating Fixture	10047498 Assembly, Pickoff
YG1158-T17	Resistor Plating Fixture	10050020 Manifold, Resistor
YG1158-T18	I/C Plating Fixture	10050022 Amplifier, Manifold

Figure 21 shows the layout of the production plating line, and Table 6 contains a listing of the purchase tooling required to set up the line.

EQUIPMENT NEEDED FOR TESTING

Test equipment consisted of the three major assemblies listed below, which are shown in Figure 22.

- Rate table
- Test equipment console
- Fluidic test fixtures and hydraulic power supply

Table 7 lists these assemblies by part number, and the equipment drawings are shown in Appendix D.

Rate Table -- This piece of test equipment supplies the rate input that results in a pressure output from the fluidic rate sensor. This is a special rate table in that it requires a hydraulic connection to provide for both the input and return flows of the hydraulic fluid. The rate sensor test fixture mounts on top of the rate table and provides both a holder for the rate sensor and a fixture for the plumbing required to perform the specified tests.

Test Equipment Console -- The test equipment console contains all of the equipment shown in Figure 23. It provides a tamper-proof container for all of the test equipment, which means that the equipment purchased for this program will remain in one place at all times. This type of setup has two advantages: (1) data gathered on this test setup will be consistent within the accuracy of the test equipment, as the same certified equipment will be used at all times, and (2) no time will be wasted in the gathering of test equipment and its interconnection. Setup time can become significant, especially in a testing laboratory environment.

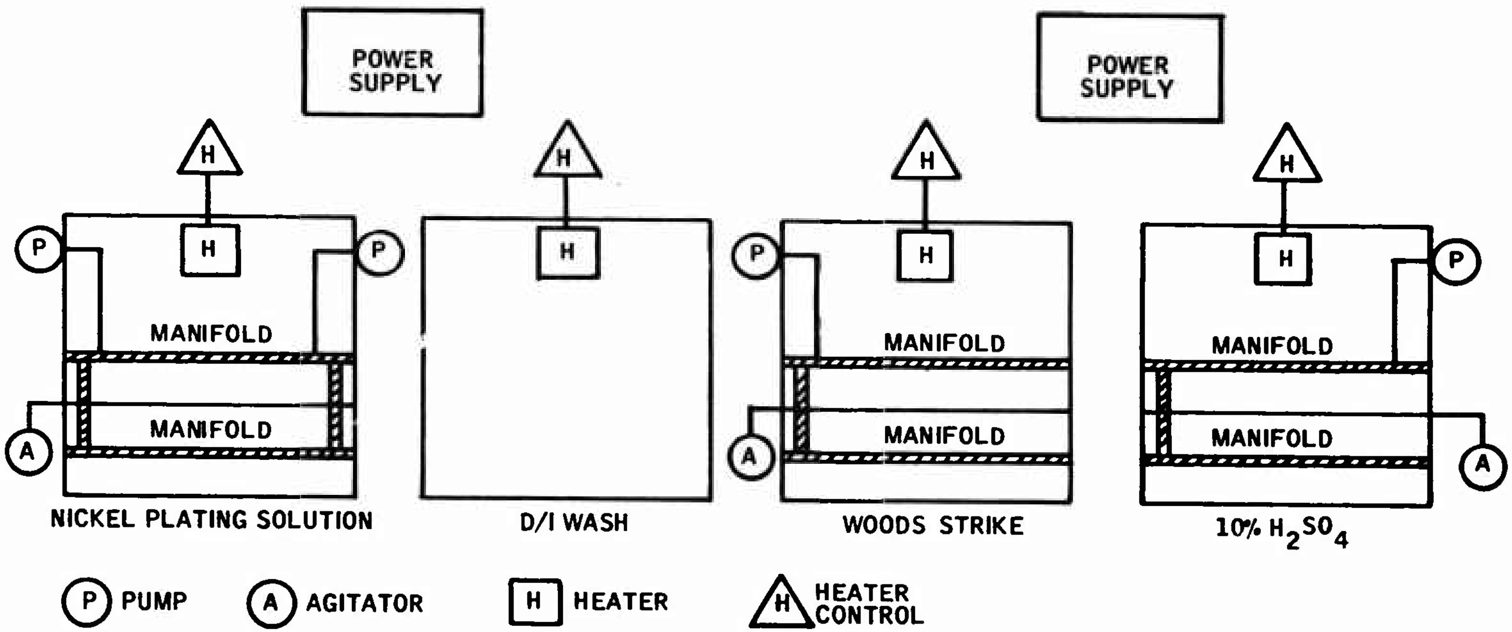


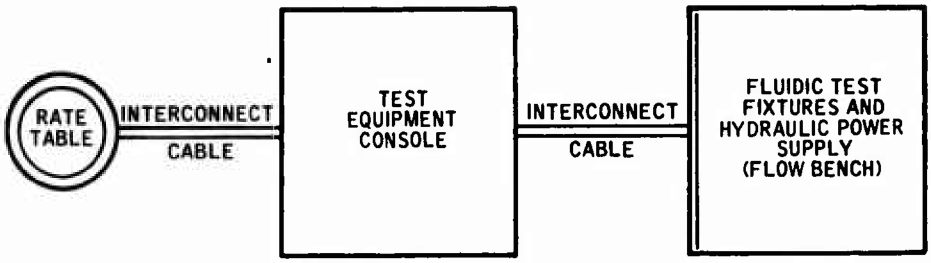
Figure 21. ECW Plating Line.

TABLE 6. PURCHASE TOOLING REQUIRED FOR PLATING LINE

Tool Part Number	Name	Quantity
YG1158-T2	Quartz Heater	1
YG1158-T3	Cancelled; see T21	-
YG1158-T4	Plating Power Supply	1
YG1158-T5	NI Anodes, Bags and Hooks	6
YG1158-T7	Plating Tank	3
YG1158-T8	Plating Tank	1
YG1158-T9	Circulation Pump	4
YG1158-T10	Filter Pump	1
YG1158-T11	Plating Materials (SNAP)*	5 lb
YG1158-T12	Plating Materials (SNAC)*	20 lb
YG1158-T13	Plating Solution (SN)*	50 gal
YG1158-T14	Plating Solution (SNS)*	10 gal
YG1158-T16	VRS Plating Fixture**	1
YG1158-T17	Resistor Plating Fixture**	1
YG1158-T18	I/C Plating Fixture**	3
YG1158-T20	Cathode Rod Agitator	3
YG1158-T21	Flushing Pump	1
YG1158-T22	1 kw Tank Heater	3

*Consumed during plating

**Assembly tooling included for reference only.



DEFINITION	FUNCTION
RATE TABLE	PROVIDE RATE INPUTS TO FLUIDIC RATE SENSOR
TEST FIXTURES AND HYDRAULIC POWER SUPPLY	PROVIDE HOLDING PLATFORM FOR THE AMPLIFIER TEST FIXTURE (YG1158T102) AND FOR THE PILOT INPUT DEVICE (YG1158T105). ALSO PROVIDE THE FRAMEWORK FOR THE HYDRAULIC POWER SUPPLY (FLOW BENCH).
TEST EQUIPMENT CONSOLE	PROVIDE A SEALED ENVIRONMENT FOR ALL OF THE VARIOUS PIECES OF TEST INSTRUMENTATION.

Figure 22. Test Equipment.

TABLE 7. MAJOR TEST EQUIPMENT ASSEMBLIES

Tool Part Number	Name	Quantity
YG1158E100	Fluidic Test Station	1
YG1158E101	Test Station Control Panel	1
YG1158E102	Hydraulic Test Bench	1
YG1158E103	Amplifier Test Fixture	1
YG1158E104	Connector Interface Panel	1
YG1158E105	PID Test Fixture	1
YG1158E106	Rate Sensor Test Fixture	1
YG1158E107	Indicator Panel	1

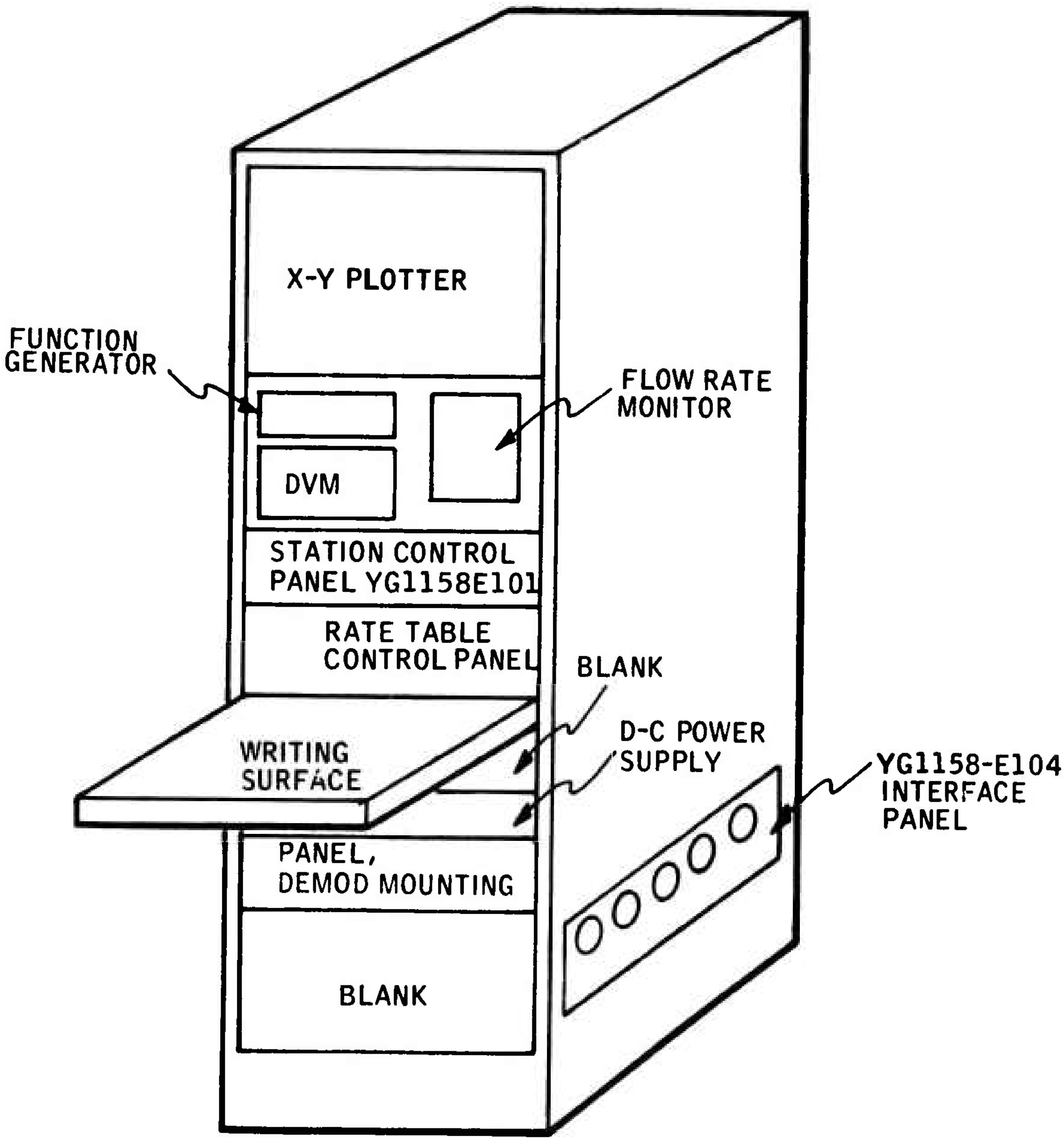


Figure 23. Test Equipment Console (YG1158E100).

Fluidic Test Fixture and Hydraulic Power Supply -- The hydraulic fluid used to power both the integrated circuit (I/C) and the rate sensor is contained in the hydraulic test bench shown in Figure 24. The test bench provides the hydraulic fluid at the correct temperature and pressure for testing these fluidic components, and it is flexible such that the test equipment can be located in any area. The test bench also provides a mounting surface for the I/C test fixture and the pilot input device test fixture, which are hard-plumbed into the hydraulic test bench with the pressure outputs being monitored by electronic pressure transducers. These transducers are connected by cables to the test equipment console, which is then used to record the test data gained during a specific test.

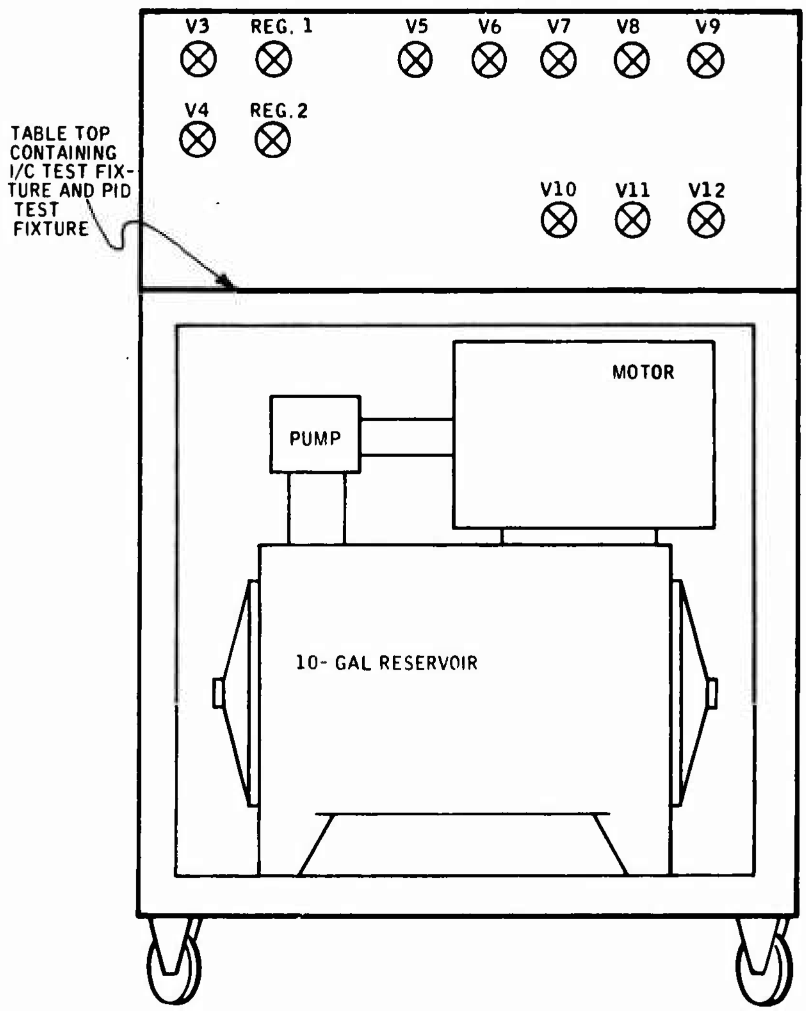


Figure 24. Hydraulic Test Bench.

SECTION VI
CONCLUSIONS

- The developmental work has shown the feasibility of incorporating the amplifiers, resistors, and interconnecting channels on an integrated circuit manifold. Using the integrated circuit and incorporating the design changes explained in this report, this configuration will be used to begin Phase II.
- The pilot production line, as defined in this report, will be implemented.

APPENDIX A

ENVIRONMENTAL TEST PLAN

1.0 SCOPE

This test plan defines the procedures followed for qualification testing of the yaw SAS controller and servoactuator (Yaw Axis Hydrofluidic Stability Augmentation System). The environmental tests consisted of temperature tests, vibration tests, and open-loop response tests. The unit operated with working fluid temperatures from 40° to 180°F.

2.0 APPLICABLE DOCUMENTS

a. DS 24470-01

b. MIL-STD-810B Environmental Test

c. MIL-H-5606 Hydraulic Fluid

3.0 TEST REPORTS

a. Test reports shall be standard Honeywell format.

b. DCAS witnessing is required for this testing.

4.0 TEST ITEM

a. The system shall consist of a hydrofluidic controller and a hydraulic servoactuator. The hydrofluidic controller may be tested separately or with the servoactuator.

b. The system design goals shall be as listed in Paragraph 3.4 of DS 24470-01.

5.0 STANDARD TEST CONDITIONS

a. Unless otherwise specified, all tests will be run at standard room-temperature conditions (70 ± 5°F) and at room barometric pressure.

b. Mounting: All tests, unless otherwise specified, shall be conducted with the controller mounted as it would be on the servoactuator. The servoactuator will be mounted with the output axis horizontal. All of the components comprising the system will be rigidly mounted to the test fixture. All connections with the exception of the power supply and the return lines shall be with rigid tubing.

c. Standard Power Flow: Standard hydraulic power for the unit shall be MIL-H-5606 hydraulic fluid. The power supply shall be capable of supplying 8 in.^{3}/sec at an input pressure of 600 psig. Standard fluid operating temperature will be 120° ± 5°F. All fluid flow supplied to the system will be filtered to 10 microns absolute.

6.0 TEST SCHEDULE

Temperature, vibration, and open-loop response tests will be conducted in that order.

7.0 TEMPERATURE TESTS

a. Mount the system on the rate table in the standard configuration. Stabilize the oil temperature at -25°F or as cold as practical with existing equipment. Apply a sinusoidal input rate of ±2 deg/sec at 0.4 cps to the system. Energize the system and record the servoactuator or controller output. Increase the oil temperature to 40°F and allow it to stabilize. Cover the system with a box or blanket to reduce the temperature gradient between ambient and oil temperature. Apply sinusoidal input rates of ±2 deg/sec at frequencies of 0.01, 0.02, 0.04, 0.1, 0.2, 0.4, 1.0, 2.0, 4.0 and 10 cps. Record the output of the servoactuator or controller. Repeat the test at the same frequencies with the input amplitude increased to ±5, ±10, and ±15 deg/sec.

   Record the output from the test unit with no input rate applied to the system. The total peak-to-peak noise and null of the system will meet the equivalent requirements of Paragraphs 3.4.4 and 3.4.7, respectively, of DS 24470-01.

b. Repeat the tests of paragraph 7a at oil temperatures of 60°, 90°, 120°, 180°F.

c. The output of the test unit will meet the equivalent requirements of Figure 2 of DS 24470-01, or Figure B-2 of this report.

d. Apply a mechanical input to the rudder input device under the same conditions as in paragraph 7a and 7b. Total peak-to-peak motion of the input measured at the end of the control cable shall be 0.02 ± 0.005 inch. Apply frequencies of 0.01, 0.04, 0.1, 0.4 and 1.0 cps, and record the output of the test unit. Repeat the test at amplitudes of 0.04 and 0.08 inch of control cable motion. The output of the test unit will meet the equivalent requirements of Figure 3 of DS 24470-01, or Figure B-3 this report.

e. Rotate the Built in Test (BIT) actuator on the controller clockwise (CW). Allow sufficient time for the test unit output to decay and release the BIT actuator. Record the test unit output during this complete test. Repeat this procedure at each temperature.

f. Apply a steady rate of 10 deg/sec CW to the system while recording the output. Allow sufficient time for the test unit to stabilize. Remove the rate and again allow the test unit to stabilize. The gain shall meet the equivalent requirements of paragraph 3.4.5 of DS 24470-01. Repeat the test in the counter-clockwise (CCW) direction and at rates of 30° and 50°/sec. This test shall be run at each temperature.

8.0 VIBRATION TESTS

a. Mount the complete system in the standard configuration on a vibration driver. The axis of the input vibration will be vertical and parallel with the rate sensor input axis. Supply the system with standard flow and pressure. The temperature of the fluid will be 120° ± 5°F.

b. Vibrate the complete system while it is energized and operating. The vibration amplitude and frequency shall be according to Curve M of Figure 514-1 of MIL-STD-810B. Record the test unit output during the complete test, and note the frequency where the test unit oscillates or null shift occurs. Vibrate the system at those frequencies where the null shift was greater than 0.05 inch or equivalent controller output for 10 minutes.

c. Remount the system such that the axis of vibration is parallel to the servoactuator ram axis. The rate sensor input axis should still be vertical. Vibrate as in paragraph 8b.

d. Rotate the system 90° about the rate sensor input axis and repeat paragraph 8b.

e. During all of the vibration tests, there shall be no increase in leakage from the system, and there shall be no line breakage or failure of fittings in the system. The maximum null shift shall be 0.05 inch of equivalent servoactuator output.

9.0 OPEN-LOOP TESTS

a. Remount the system on the rate table. Energize the system and supply it with standard flow and pressure. Allow the system to stabilize at 120° ± 5°F. Apply input rates of ±2 deg/sec at 0.01, 0.02, 0.04, 0.1, 0.2, 0.4, 1.0, 2.0, 4.0 and 10 cps. Record the outputs of the test unit.

b. Repeat the above tests with an input of ±10 deg/sec. Record the output of the test unit.

c. The results will meet the equivalent requirements of Figure 2 of DS 24470-01, or Figure B-2 this report.

d. Apply rudder inputs as described in paragraph 7d. Record the test unit output.

e. The results will meet the equivalent requirements of Figure 3 of DS 24470-01, or Figure B-3 this report.

f. The noise and null recorded with no rate input will not exceed the equivalent requirements of paragraphs 3.4.4 and 3.4.7 of DS 24470-01.

g. Perform the tests of paragraph 7e of this document.

h. Perform the tests of paragraph 7f of this document.

APPENDIX B

DETAIL SPECIFICATION,
YAW-AXIS HYDROFLUIDIC
STABILITY AUGMENTATION SYSTEM
DS24470-01

1.0 SCOPE

This specification defines the performance requirements for the YG1116A01 Stability Augmentation System. The system is a hydrofluidic control package which mounts on top of the boost and SAS actuator of the OH-58A helicopter. This system is added to the aircraft to improve the handling qualities in the yaw axis.

The requirements of this specification are design goals.

2.0 APPLICABLE DOCUMENTS

The following documents and drawings and the applicable specifications referenced therein shall apply to the extent specified herein.

2.1 MIL-H-5606, Hydraulic Fluid, Petroleum Base, Aircraft, Missile and Ordnance.

3.0 REQUIREMENTS

3.1 General

The system shall consist of the following functional units:

3.1.1 Vortex Rate Sensor - Provides a differential pressure signal that is proportional to the aircraft angular rate in the yaw axis.

3.1.2 Amplifiers - Accept and amplify differential pressure signals.

3.1.3 Shaping Networks - Usually a combination of resistors and capacitors (bellows) designed to provide the following functions:

a) Lag - With a characteristic of $\frac{1}{TS + 1}$

b) High-pass - With a characteristic of $\frac{TS}{1 + TS}$

Note: T is a time constant.

3.1.4 Pilot Input Device - Provides an output which is a function of pedal displacement. This will reduce the tendency of the control system to "fight" the pilot in the yaw axis.

3.1.5 Servoactuator - If mounted effectively in series with the aircraft power boost servo, accepts differential pressure signals and converts them to displacements of the power boost servo pilot valve. Weight, bulk, and power consumption shall be optimized to the extent possible without compromising reliable and demonstrable functioning. Interunit connections shall be accomplished in a manner that will permit replacement of individual functional components.

3.1.6 Flow Control Valve - Maintains a constant flow to the system when provided a differential pressure of over 100 psid.

3.1.7 Engage Valve - Solenoid operated, hydraulic and remotely controlled from the cockpit to engage all or part of the control system.

3.1.8 Back Pressure Regulator - Maintains a constant return pressure level on the controller regardless of downstream pressure surges.

3.2 ENVIRONMENT

3.2.1 Vibration - A 15-minute vibration scan, with the system operating and output null monitored, will be conducted in each of the three axes at 5 g's from 20 to 500 Hz. The testing shall be conducted with the hydraulic supply and connections simulating the actual aircraft installation as nearly as practicable.

3.2.2 Temperature - The system shall operate over the ambient temperature range from 0° to 180°F when the operating fluid is in the range of +40°F to +180°F.

3.3 Power Supplies

3.3.1 Input power to the system shall be hydraulic fluid per MIL-H-5606 at a pressure of 600 psig (Nom), which is obtained from the aircraft hydraulic power system. The system (except augmentation servoactuators) shall not require more than $2.7 \frac{in.^3}{sec}$.

3.3.2 Electrical power for the solenoid will be 28 vdc.

3.4 System Performance

All performance requirements in this section pertain to normal operating conditions. Normal operating conditions are defined as:

- Ambient temperature - 70° ± 5°F
- Hydraulic fluid temperature - 120° ± 5°F
- Hydraulic fluid pressure - 500 to 600 psig ahead of the flow regulator; a minimum of 40 psig return pressure.

3.4.1 System requirements are summarized in Figure B-1.

3.4.2 Range - The system shall have a range of at least ±30 deg/sec ahead of the high pass and ±100 percent actuator stroke downstream of the high pass.

3.4.3 Linearity - The system linearity including the servoactuator shall be within ±10 percent of full scale. Linearity is defined as the width of the band enclosing all the test points.

3.4.4 Noise - Peak-to-peak noise at output of the actuator shall not exceed ± 0.015 inches of actuator motion.

3.4.5 Accuracy - The system shall maintain gain and time constants within tolerances shown in Figures B-2 and B-3 for the high-pass and pilot input loops.

3.4.6 Phasing - CCW rotation of the system shall cause the series servoactuator to retract. CW rotation of the PID cam shall cause the series servoactuator to retract (right pedal).

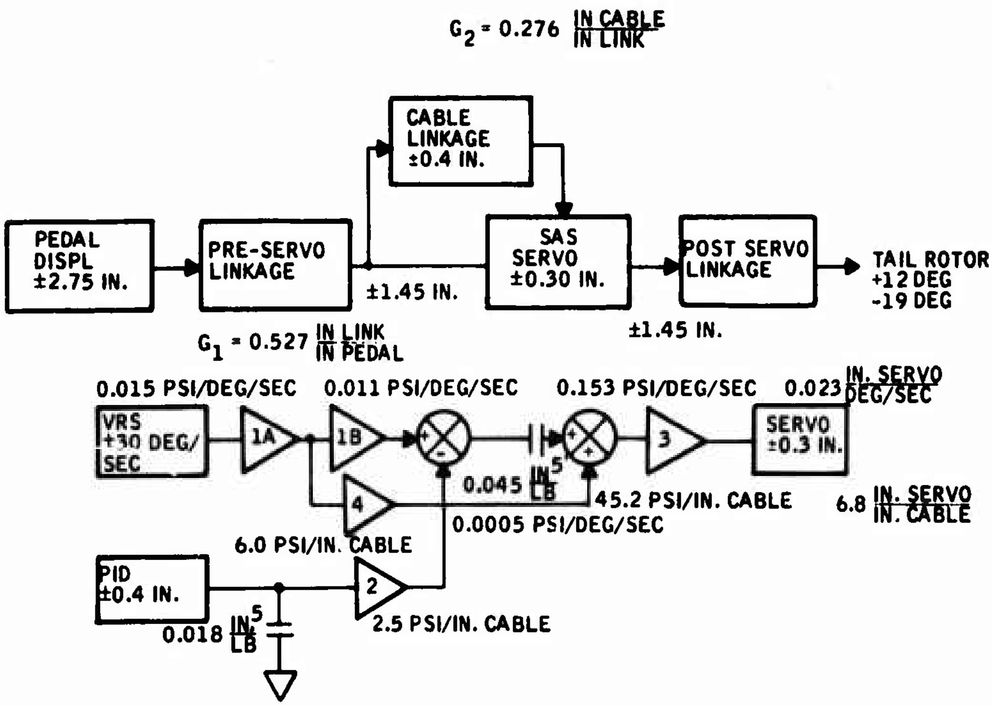
3.4.7 Null - the servoactuator null offset at zero input turning rate shall be no greater than ±0.07 in.

3.5 Component Performance

Performance shall be determined at room temperature ambient with fluid at 120° ± 5°F, unless otherwise specified.

3.5.1 The vortex rate sensor shall meet the following performance requirements when the system is supplied with 2.7 $\frac{\text{in.}^3}{\text{sec}}$:

- Scale factor 0.014 psid/deg/sec, dead ended
- Range ± 30 deg/sec, minimum



COMPONENTS

$G_{VRS} = 0.015e^{-0.06S}$ DEAD END PSI/DEG/SEC

$G_{PID} = 6.0$ PSI/IN. OF CABLE

$G_{AMP1} = 0.731$ PSI/PSI

$G_{AMP2} = 0.42$ PSI/PSI

$G_{AMP3} = 14.0$ PSI/PSI

$G_{AMP4} = 0.025$ PSI/PSI

$$G_{SERVO} = 0.15 \left[\frac{(62.8)^2}{S^2 + 2(0.7)(62.8)S + (62.8)^2}\right] \text{ IN./PSI}$$

$G_{CABLE} = 0.276$ IN. CABLE/IN. LINKAGE

$G_{LINKAGE} = 0.527$ IN. LINKAGE/IN. PEDAL

SYSTEM

RATE LOOP

$$G_R = 0.023 \left[\left(\frac{2.5S}{2.5S+1}\right)\left(\frac{3950}{S^2 + 88S + 3950}\right)\right] e^{-0.06S} \text{ IN. SERVO/DEG/SEC}$$

PID LOOP

$$G_{PID} = 6.8 \left[\left(\frac{1}{S+1}\right)\left(\frac{2.5S}{2.5S+1}\right)\left(\frac{3950}{S^2 + 88S + 3950}\right)\right] \text{ IN. SERVO/IN. CABLE}$$

Figure B-1. System Performance (Yaw).

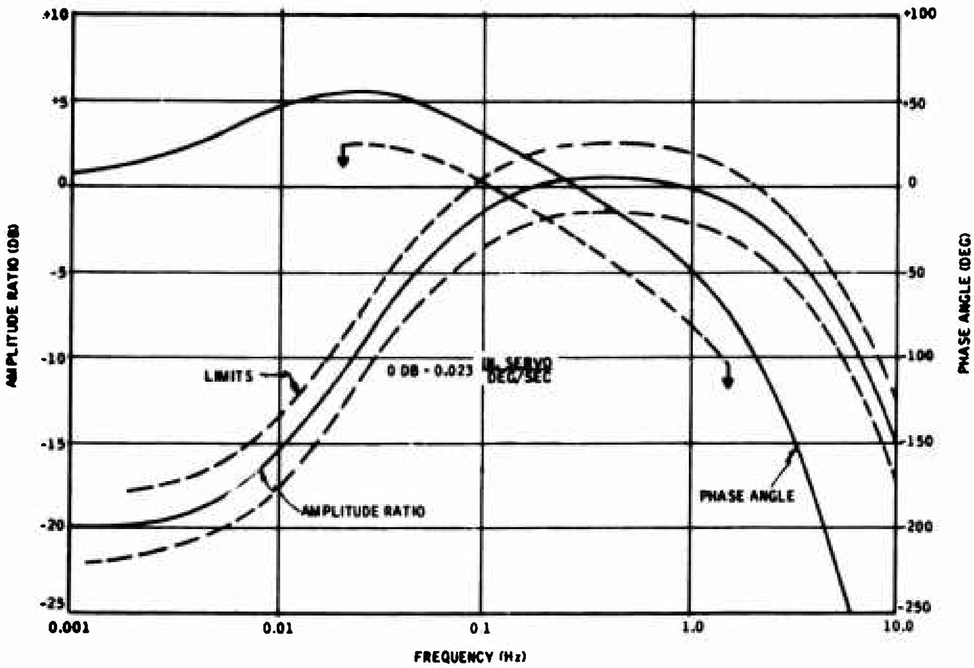


Figure B-2. Rate Transfer Function Requirements.

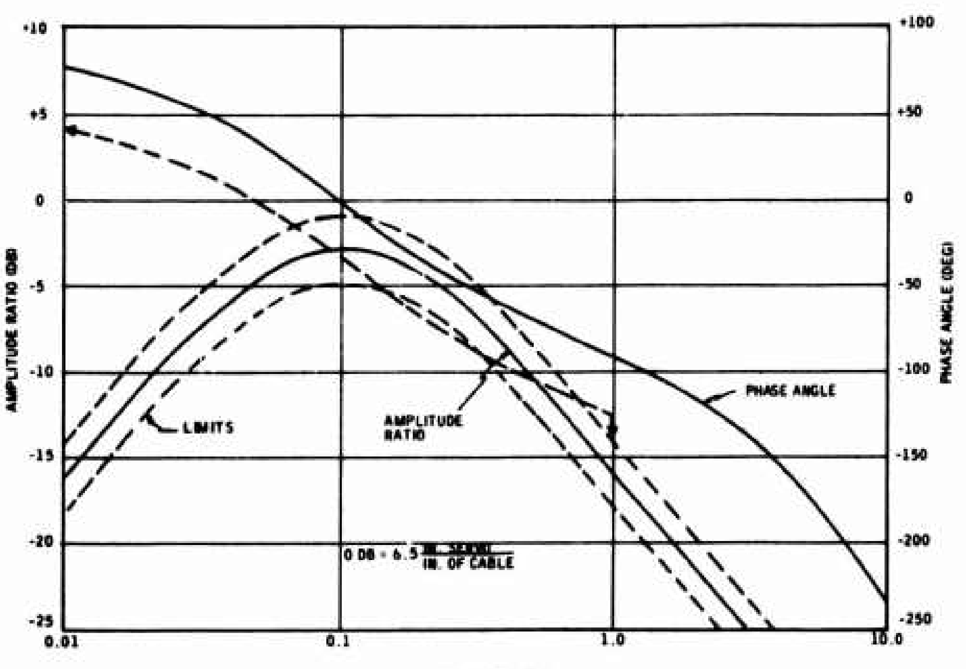


Figure B-3. Pilot Input Transducer Transfer Function Requirements.

- Linearity - ± 5 pct of full scale
- Time Delay - 0.060 sec or less
- Noise - ± 0.65 deg/sec max
- Calibrate Button - A sensor calibrate button shall be utilized with the capability of inserting a signal equivalent to a step rate of about 5 degrees per second.

3.5.2 Amplifiers - Amplifiers shall meet the following performance requirements when supplied with a pressure of >6.5 psid.

- Input impedance for VRS load amplifier--180 ohms minimum
- Output impedance for output amplifier--100 ohms maximum
- Gain and load - Requirements for each application are described in Figure B-1.

3.5.3 Servo - The servoactuator shall meet the following performance requirements:

Quiescent level (above R_c)	5 psig ± 1 psig
Full control signal range	± 2 psig
Max (above R_c)	15 psig
R_c Max	100 psig
Effective capacitance	<0.0005 $in.^5$/lb
System pressure	600 psi
Stroke	± 0.300 in.
Threshold	1.0 pct max
Dynamic response	90° phase lag at 10 Hz (min) at 10 pct rated input
Linearity and hysteresis	± 5 pct of rated stroke
Inlet proof pressure	900 psi
Return proof pressure	600 psi
Burst pressure	1500 psi
Neutral leakage	0.10 gpm

3.6 Product Configuration

3.6.1 Drawing Number YG1116A defines the overall installation of the system.

4.0 QUALITY ASSURANCE

Conformance of the hardware to program objectives shall be evaluated with the following tests. Performance tests will be conducted before and after vibration tests.

4.1 Vibration

4.1.1 A 15-minute vibration scan, with the system operating and output null monitored, will be conducted in each of the three axes at 5 g's from 50 to 500 Hz. The testing shall be conducted with the hydraulic supply and connections simulating the actual aircraft installation as nearly as practicable.

4.2 Performance Tests

4.2.1 Conformance to dynamic range requirements of Paragraph 3.4.2 shall be determined by imposing rates of ±30 deg/sec and measuring output of the appropriate stage amplifier.

4.2.2 Gain and response requirements shall be determined by measuring system output at 0.01, 0.02, 0.04, 0.1, 0.2, 0.4, 1.0, 2.0, 4.0, and 10 Hz. Amplitudes of ± 2, ± 5, ± 10 and ± 15 deg/sec shall be used. Response shall be measured with fluid temperatures of 40°, 70°, 90°, 120° and 180°F. Results shall meet the requirements of Paragraph 3.4.

4.2.3 Gain and response of the pilot input device shall be determined by measuring system output at 0.01, 0.04, 0.1, 0.4 and 1 Hz. Amplitudes of ± 0.01 and ± 0.04 in. of cable shall be used. Response shall be measured at the same temperatures as in Paragraph 4.2.2. Results shall meet the requirements of Paragraph 3.4.

4.3 Verification

4.3.1 Inspect the systems for quality of workmanship and conformance to installation drawing.

4.3.2 Determine that the system contains the features described in Paragraph 3.6.1.

4.3.3 Establish that the power required does not exceed the amount specified in Paragraph 3.3.1.

APPENDIX C

DEVELOPMENT AND EVALUATION LAB ENGINEERING TEST REPORT

1.0 ABSTRACT

Object: To conduct qualification testing of the YG1158A01 Yaw HYSAS for Phase I of the Producibility Study Program according to Attachment 1 of the contract document DAAJ02-74-C-0012/USAAMRDL.

Summary: Because no actuator was available for this test, output differential pressures were recorded and a conversion factor of 0.15 inch/psid was used. Results are presented in graphical and tabular form for the temperature and open-loop tests. Vibration test results were satisfactory. Except for very small regions on the frequency response graphs, phase goals were met. Nominal operating temperature goals were attainable; however, refinement of the amplitude characteristics, noise, and null shifts at low temperature was abandoned as a new integrated configuration was being developed.

The tests were monitored by DCAS and Honeywell Quality Control personnel.

It is noted that the MIL-H-5606 oil in the flow bench has a viscosity at 120°F equivalent to new oil at 143°, and at 180° equivalent to new oil at 210°. The temperatures required by the specification were used. The lower viscosity bench oil could influence the characteristics of the system.

2.0 UNIT TESTED

One YG1158A01 Yaw Axis Hydrofluidic Stability Augmentation System (HYSAS) was tested without a servoactuator. The outstanding feature of this system is that the amplifiers were electroformed into an integrated manifold circuit. The schematic diagram of the circuit is shown on drawing number C13789AA01. The configuration used for this test is shown as Figure C-1.

3.0 REFERENCE DOCUMENTS

- Attachment 1 of Contract DAAJ02-74-C-0012 specifies the environmental test plan.
- DS 24470-01 lists the system performance goals for this test.

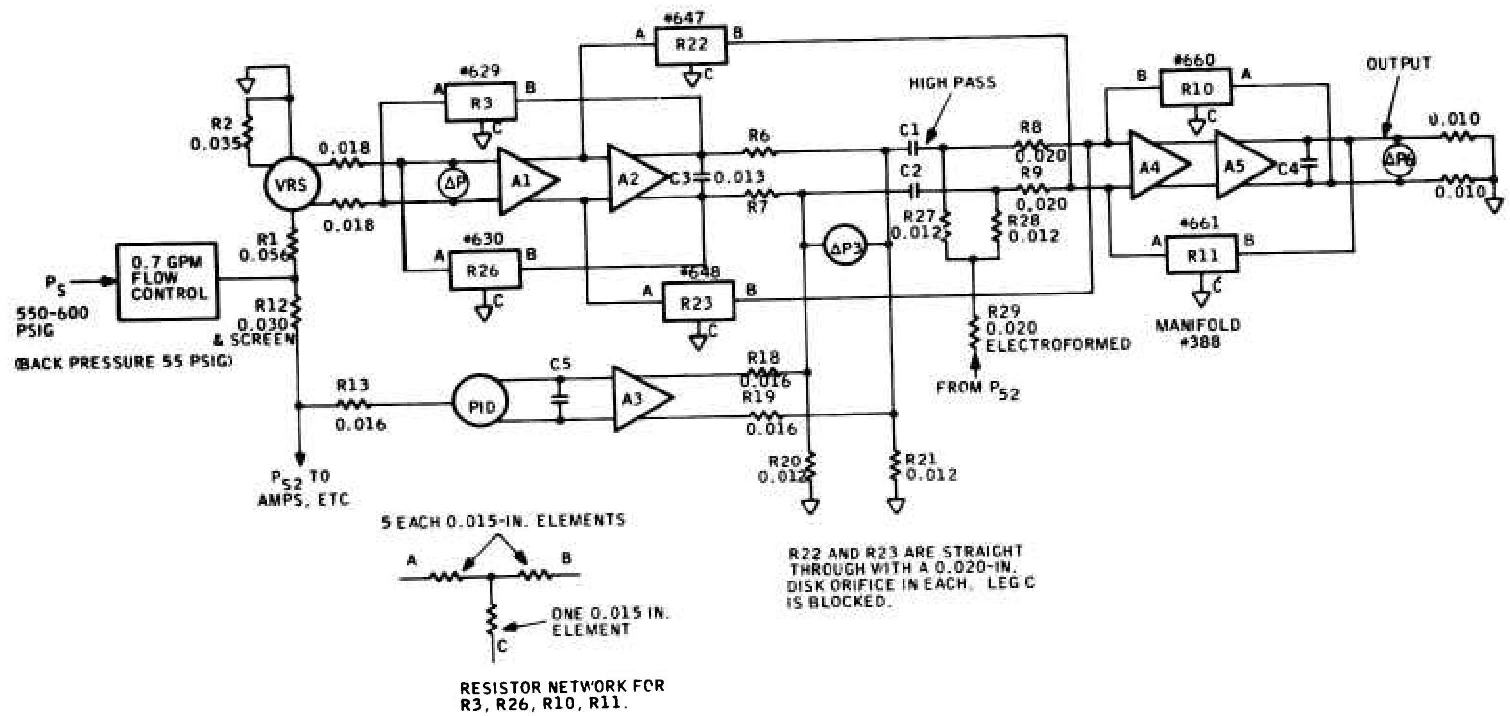


Figure C-1. Configuration for Qualification Tests – Yaw SAS.

- DS 24860-01 lists the goals for the YG1143 HYSAS, a similar circuit without the servoactuator, which was used as a guide.
- MIL-STD-810B Environmental Test

4.0 PROCEDURE AND RESULTS

The tests were conducted in the following sequence:

1. Temperature
2. Vibration
3. Open-loop response

4.1 Temperature Tests

The system, mounted on a rate table, was instrumented to measure, record, or provide:

- Output differential pressure
- Rate table sinusoidal inputs at various frequencies, steady-state inputs, and outputs
- Pedal input cable drive (hydraulic rotary actuator) and input linear pot, at the device, with power supply
- Oil temperature at the outlet of the system
- Oil flow through the system.

Hydraulic power was sent to the system through a heat exchanger with the temperature regulated by a Hi-Lo Temperature Control Unit. The input pressure at the system was maintained between 550 and 600 psig and at the outlet at 55 psig. A 2-micron filter and hard tubing were connected directly to the inlet. The system was covered by towels to minimize heat loss.

At exit oil temperatures of 46° (lowest obtainable with the setup), 60°, 90°, 120°, 150° (extra test), and 180°F, the following tests were made:

1. Sinusoidal input rates of ±2, ±5, ±10, and ±15 deg/sec were applied at frequencies of 0.01, 0.02, 0.04, 0.1, 0.2, 0.4, 1.0, 2.0, 4.0, and 10 Hz. A Bafco Frequency Response Analyzer was used to apply the input signal and to display the frequency response data. The system frequency response data was recorded and plotted. The pedal input level was centered for these tests.

X-Y gain plots were made at the same four amplitudes for pressure output versus rate input at about 0.1 Hz. X-Y time-travel plots were made of the output while the BIT was rotated to the end of its travel, held until stabilized, and released. BIT sensitivity, noise, and off-null information is indicated by the plot.

2. X-Y time-travel plots were made of the output at steady-state rates of 10, 30, and 50 deg/sec. First, a CW rotation was imposed and held until stable; then the motion was stopped until the output was leveled, and the process was repeated in the CCW direction.

3. Sinusoidal inputs were applied to the pedal input cable actuator to produce peak-to-peak motions at the lever of 0.08 (±0.04), 0.04, and 0.02 inch at frequencies of 0.01, 0.04, 0.1, 0.4, and 1.0 Hz by using the Bafco Analyzer. The frequency response data was obtained as was done for the rate.

   X-Y gain plots were made at the three amplitudes for pressure output versus cable movement at 0.1 Hz.

The frequency responses of the rate and pilot input device (PID) loops are shown in Figures C-2 through C-5. Response data for 120°F fluid temperature, before and after vibration, is shown in Figures C-2 and C-4. Response data taken at various temperatures is shown in Figures C-3 and C-5. Other response data taken at various input levels is not shown due to the similarity of results with the presented data.

Tables C-1 and C-2 summarize the rate loop and PID performance at various fluid temperatures. This data was obtained from many recordings, some of which are shown in Figures C-6 through C-8. These figures show the rate loop and PID performance at 120°F fluid temperature and are representative of the recordings taken at the other fluid temperatures.

4.2 Vibration

Vibration machine mountings were made such that the system could be vibrated in each of the three mutually perpendicular axes while maintaining the rate sensor input axis vertical.

For the hydraulic supply, a 2-micron filter was connected directly to the system, flexible hoses were used, and pressure gages and the back-pressure regulator were connected away from the vibration machine. The supply pressure was set to 640 psig and the back pressure at 50 psig. Exit oil temperature was maintained at 120° ± 5°F.

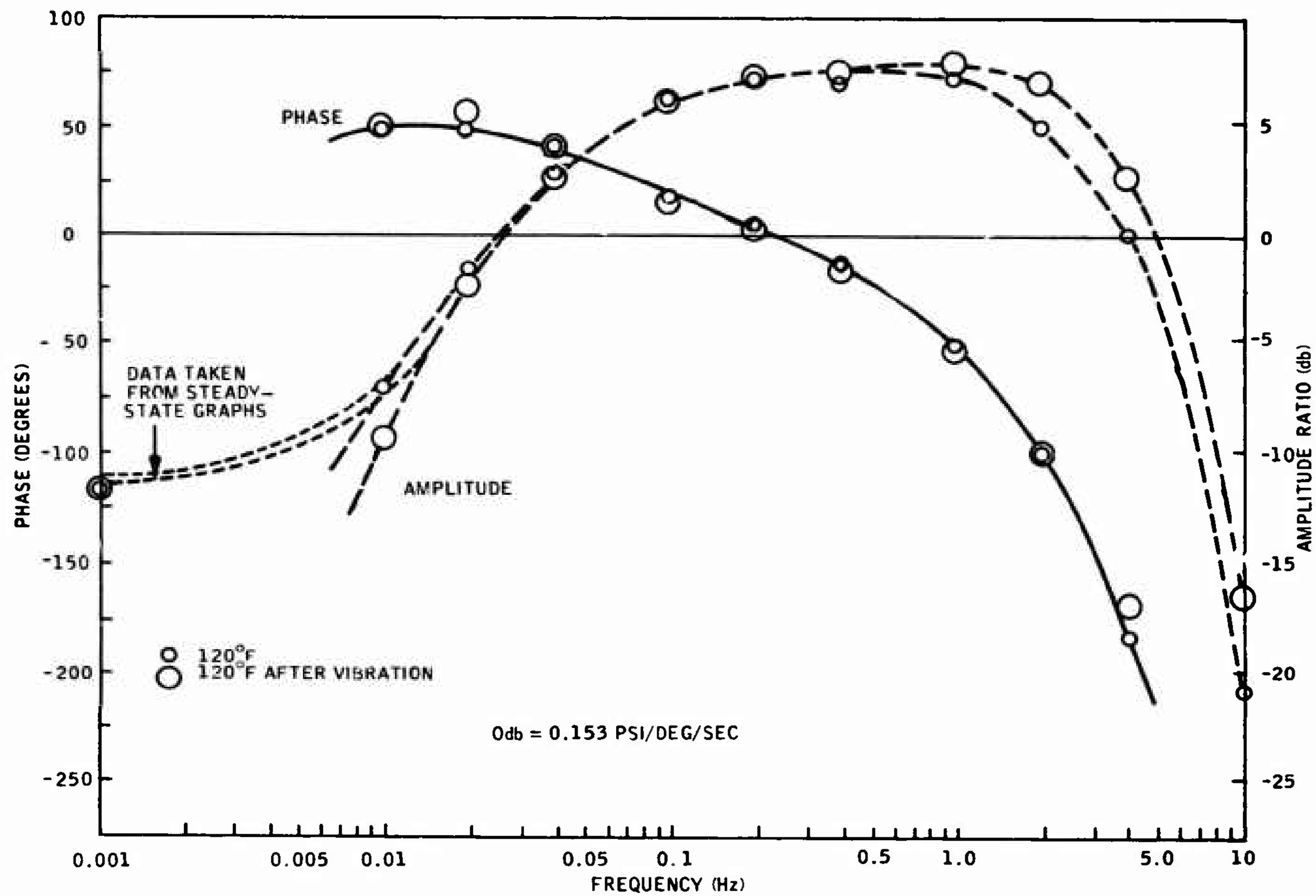


Figure C-2. Yaw SAS Frequency Response.

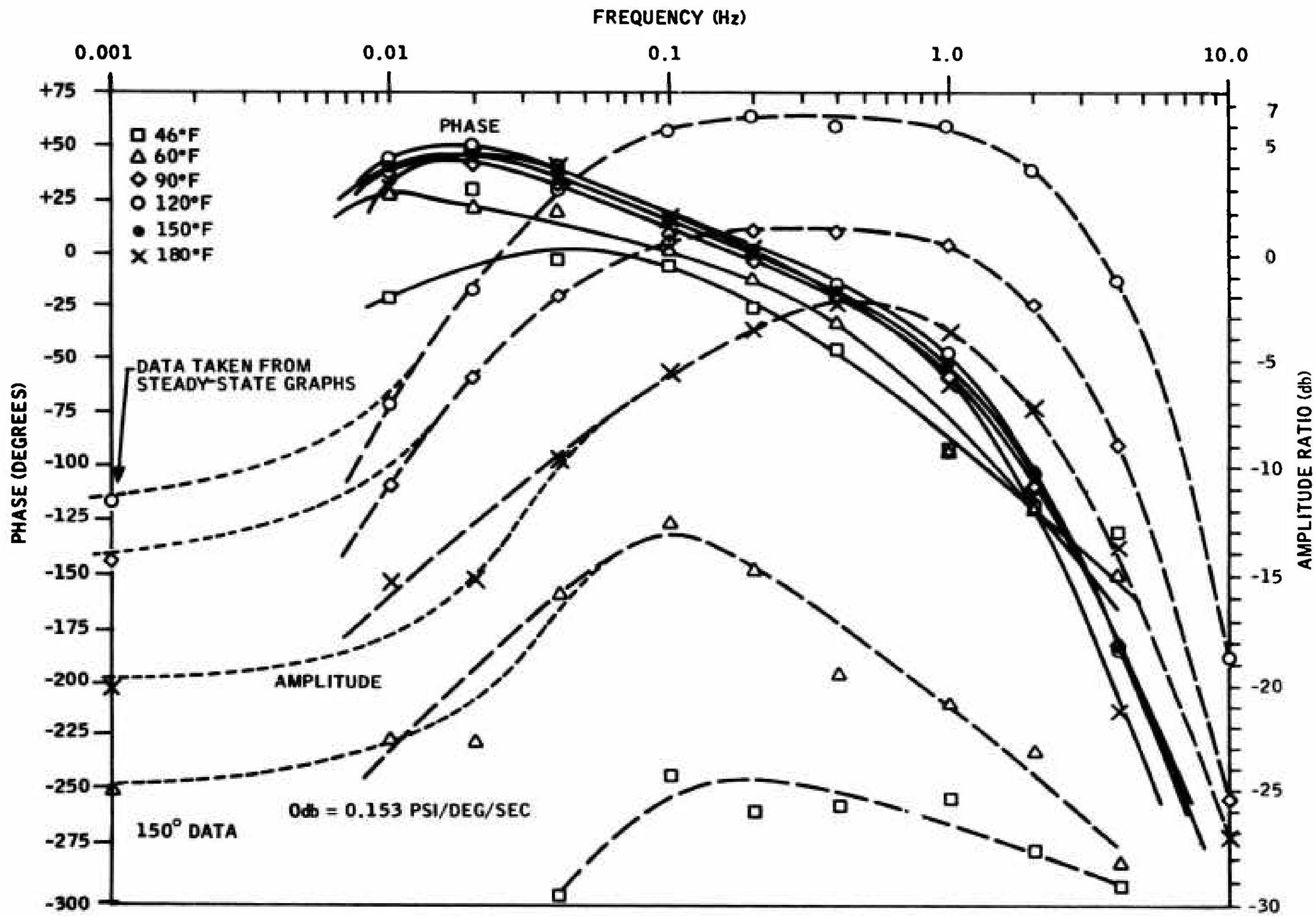


Figure C-3. Yaw SAS Frequency Response.

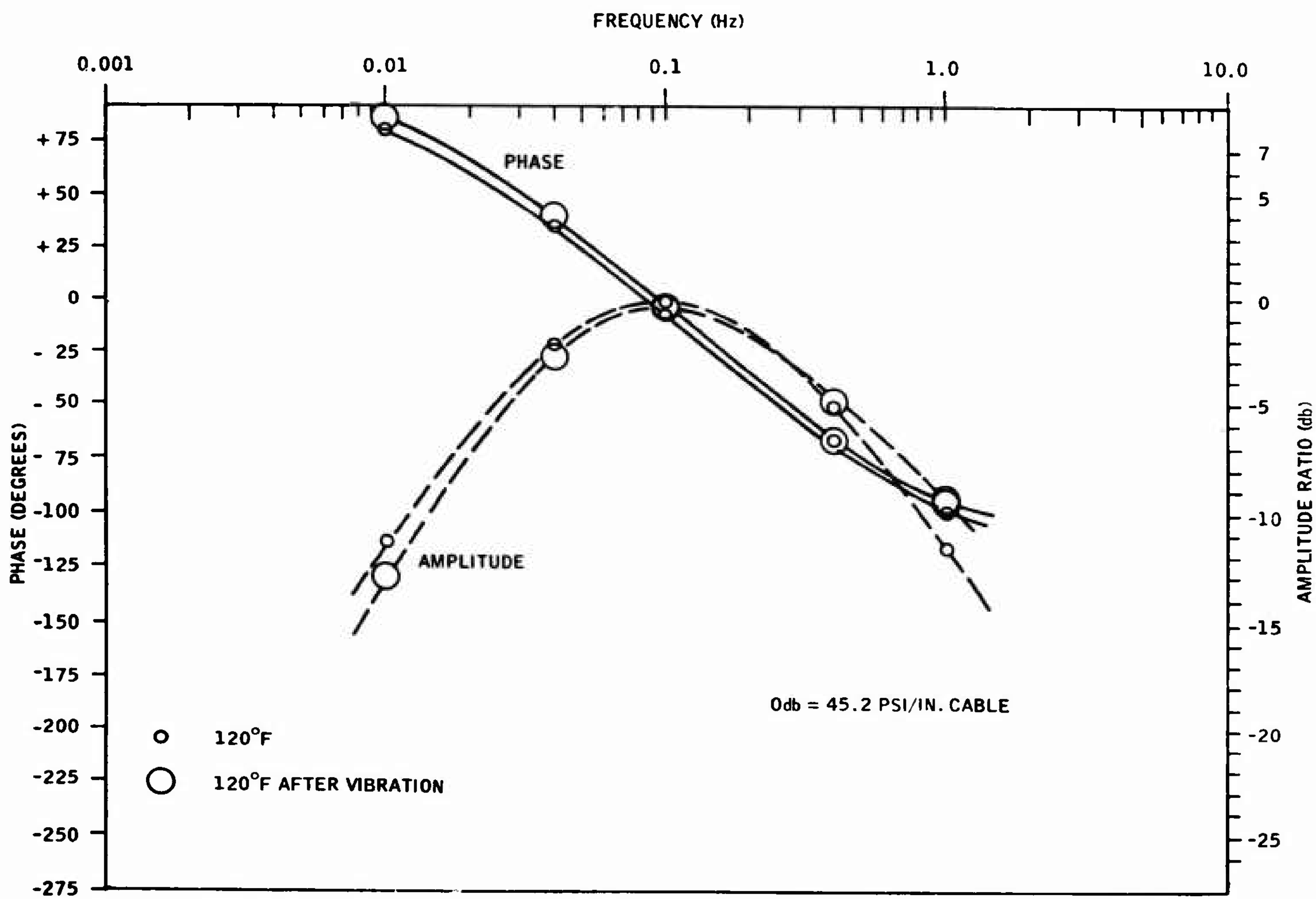


Figure C-4. PID Loop Frequency Response.

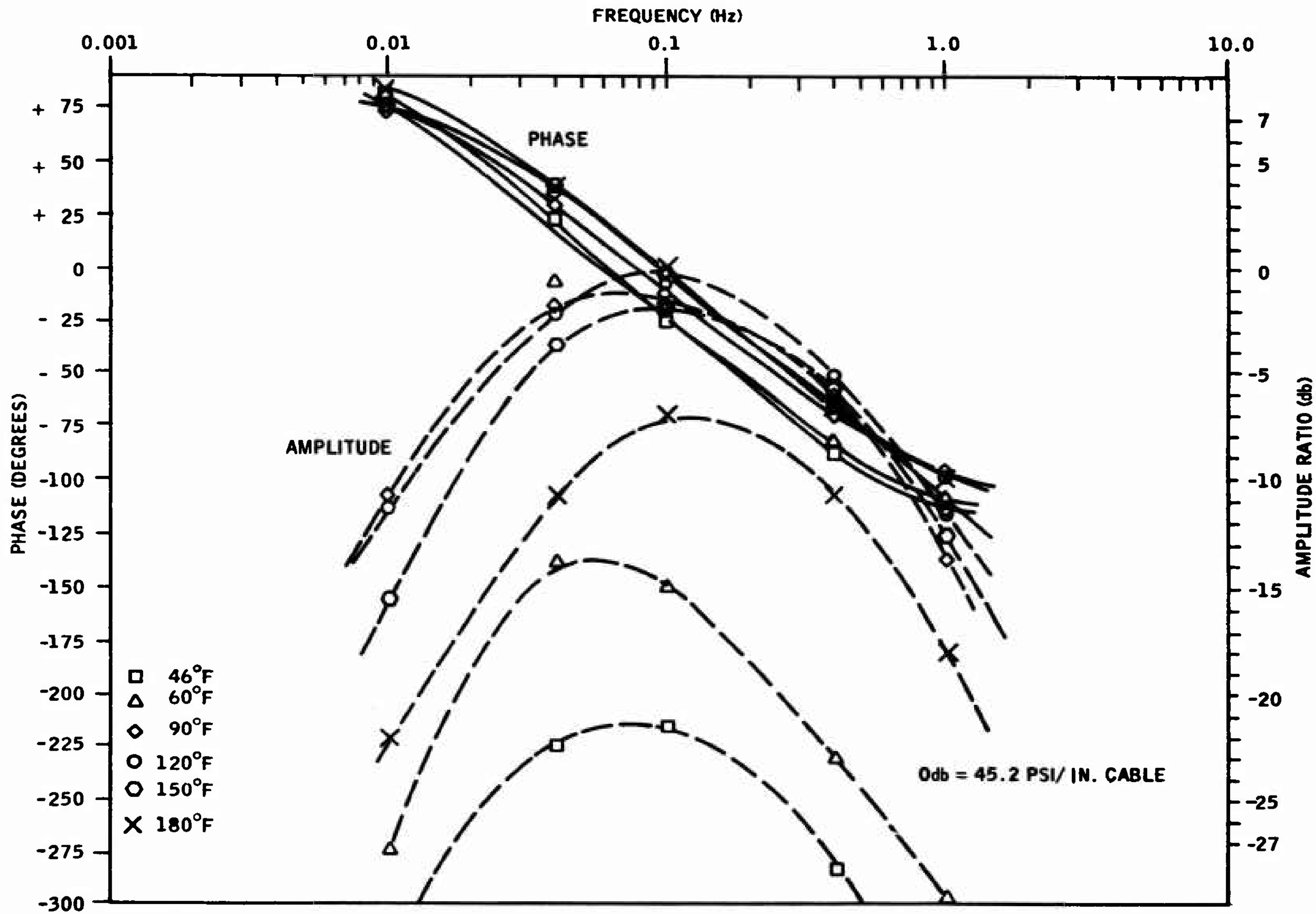


Figure C-5. PID Loop Frequency Response.

TABLE C-1. RATE LOOP PERFORMANCE VERSUS FLUID TEMPERATURE

Fluid Temp (°F)	Rate Gain (psi/deg/sec)				Null Offset (psi)	Noise (psi)	Steady-State Gain	
	±2 deg/sec	±5 deg/sec	±10 deg/sec	±15 deg/sec			psi/deg/sec	% Rate Gain
46	0.0077	0.0074	0.0077	0.0087	1.55	0.010	0.0045	61
60	0.0260	0.0200	0.0250	0.0190	1.85	0.025	0.0125	62
90	0.1340	0.1480	0.1660	0.2000	1.45	0.050	0.0300	20
120	0.2700	0.2800	0.2700	0.2800	0.20	0.250	0.0360	13
150	0.2100	0.1440	0.1350	0.1750	-	0.750	0.0250	17
180	0.0920	0.1080	0.0890	0.0740	0.25	0.625	0.0170	16
120 (Post-vibration)	0.3360	-	0.3380	-	0.20	0.250	0.0360	11

TABLE C-2. PILOT INPUT DEVICE (PID) PERFORMANCE VERSUS FLUID TEMPERATURE

Fluid Temp (°F)	PID Gain (psi/in.)		
	±0.01 inch cable input	±0.02 in.	±0.04 in.
46	2.3	2.6	3.1
60	6.1	5.7	8.8
90	26.8	28.6	42.4
120	38.1	42.2	44.9
150	36.1	39.5	37.0
180	18.0	17.9	18.9
120 (Post-vibration)	39.3	37.4	43.2

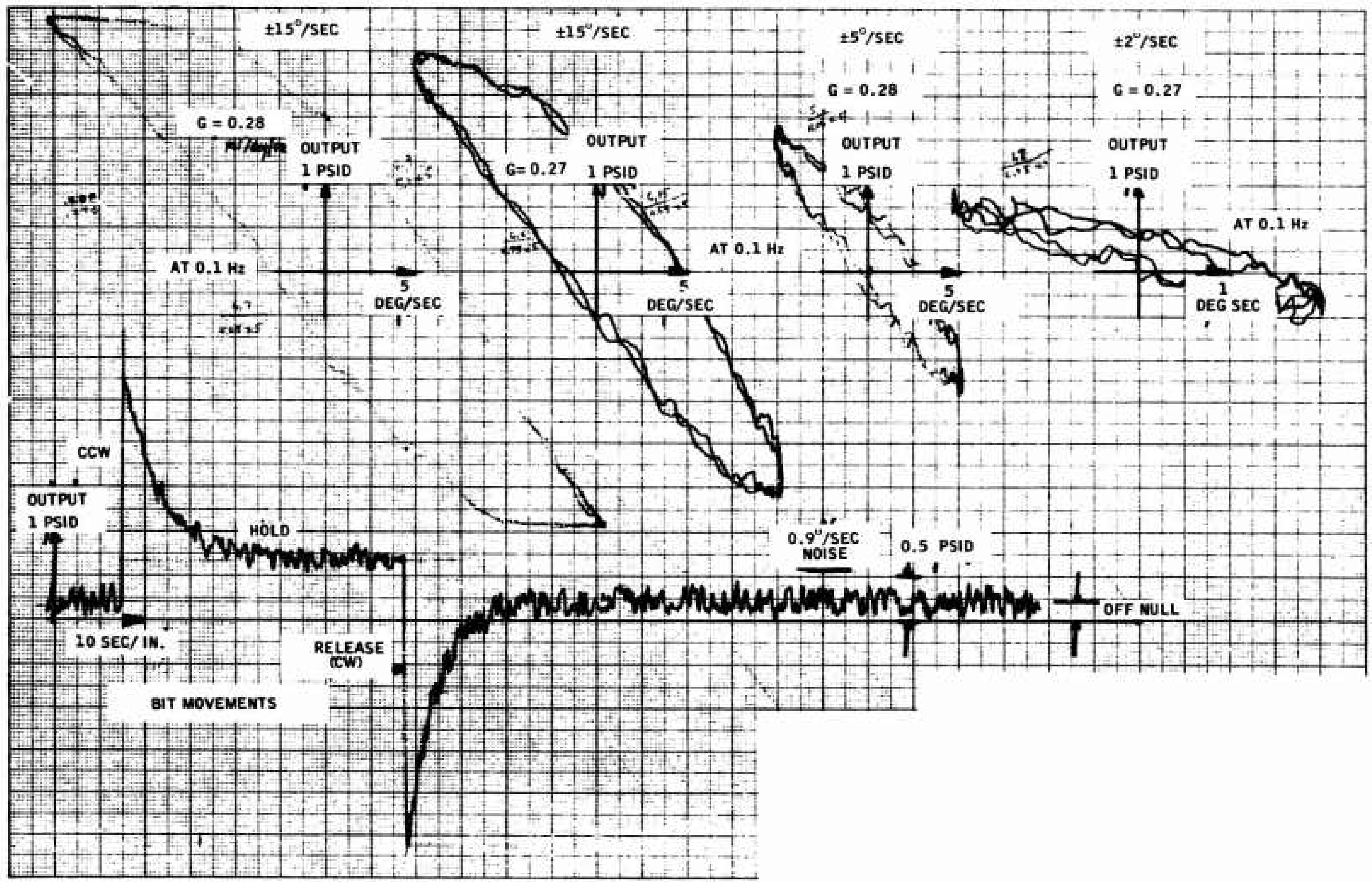


Figure C-6. Yaw SAS Gains, BIT, Noise, and Null at 120°F.

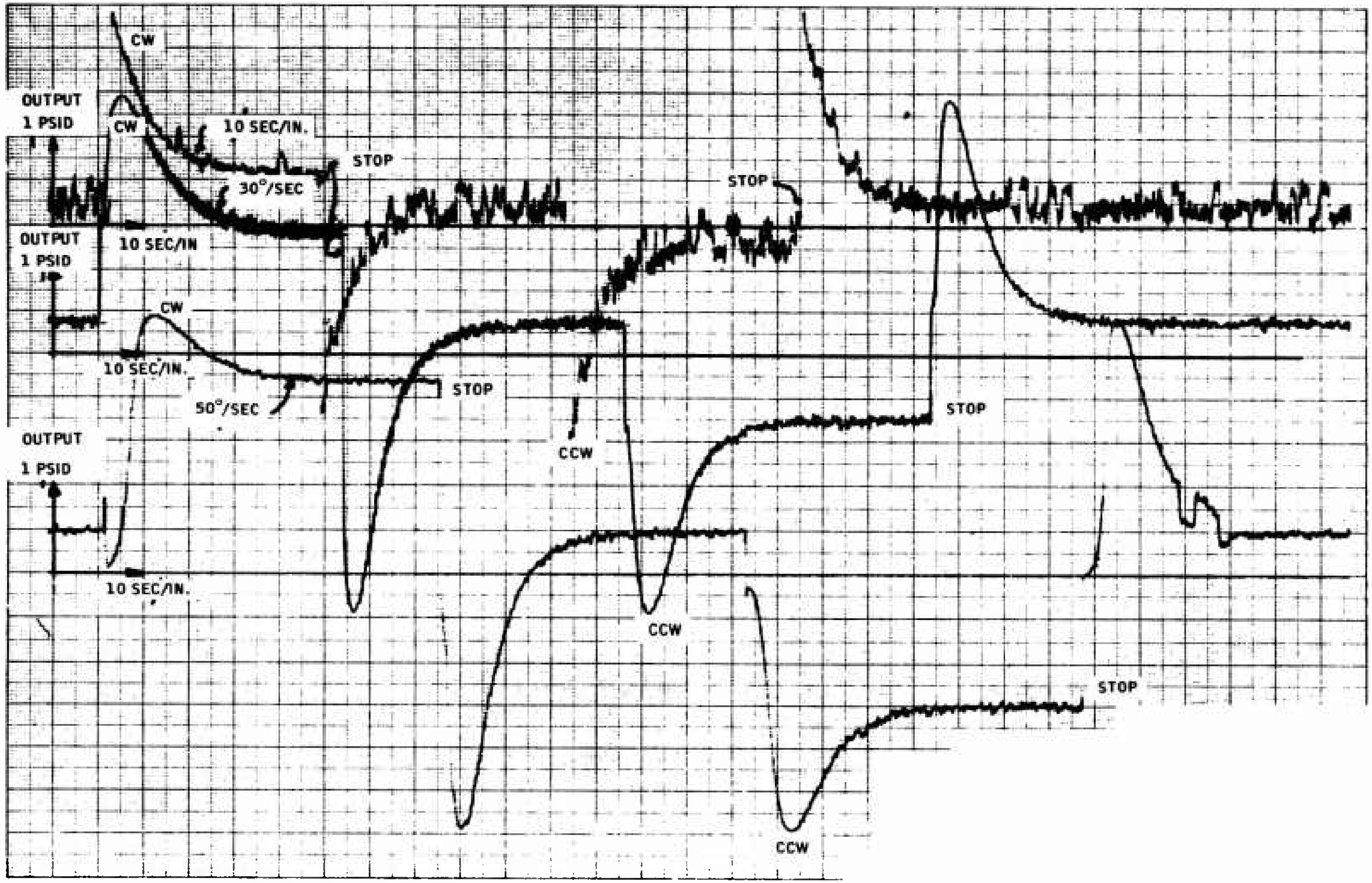


Figure C-7. Yaw SAS Steady - State Rates at 120°F.

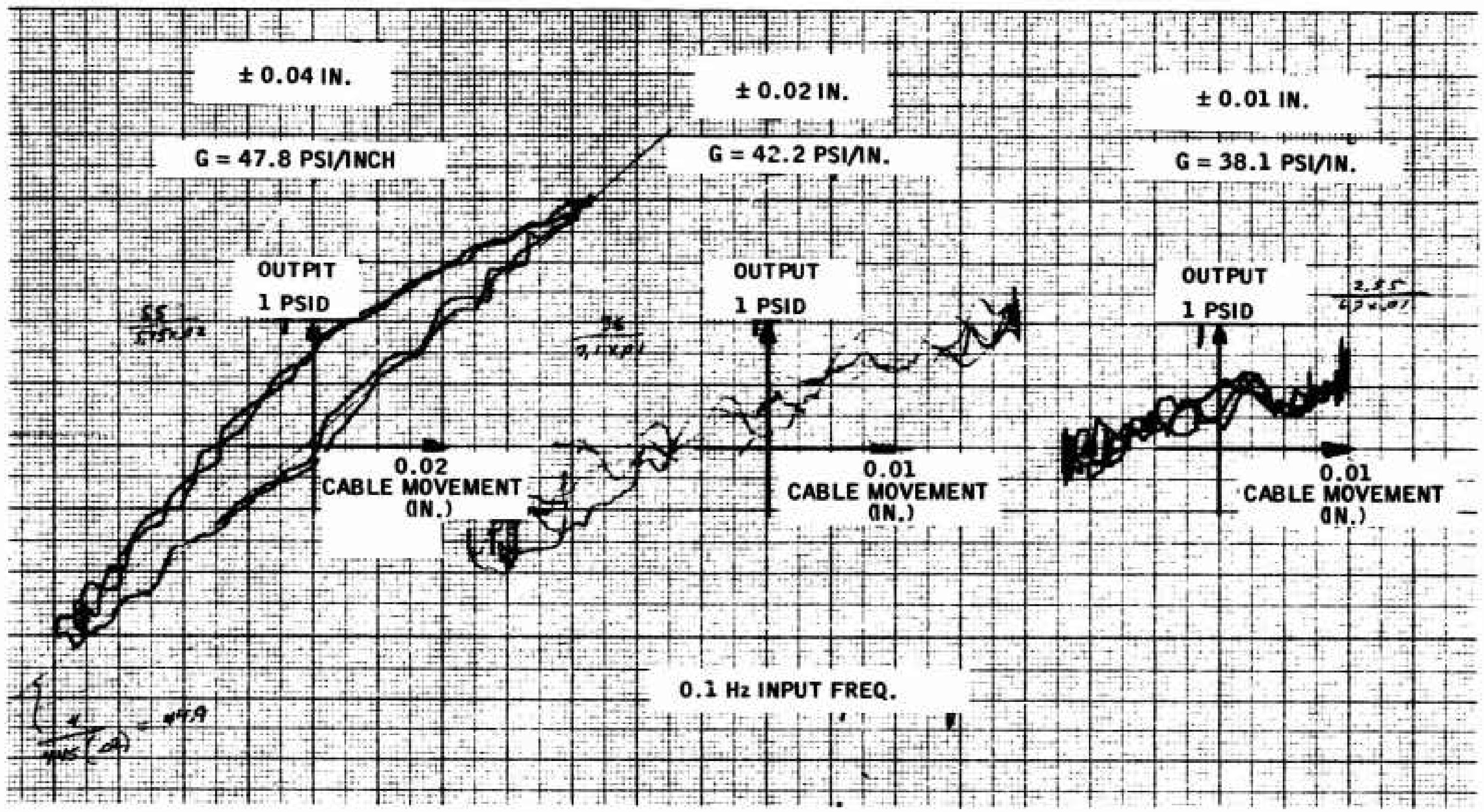


Figure C-8. Yaw SAS Pedal Input Gains at 120°F.

Fifteen-minute vibration scans were run from 5 to 500 Hz and back, following the amplitudes and frequencies shown on curve M of Figure 514-1 of MIL-STD-810B for each of the three axes. The system output was recorded on one channel of a four-channel Sanborn recorder to observe null shifts.

Two of the vibration axes indicated no excessive null shifts. For the vertical vibration axis parallel to the rate sensor axis, a momentary excessive null shift was indicated at 125, 305, and 315 Hz. Ten-minute vibration was sustained at 125 and at 310 Hz; the null remained constant and no adverse effects were noted. The vibration tests produced no leakage.

4.3 Open-Loop Response

The tests of paragraph 4.1 were repeated at 120°F except that the rate inputs at ±5 and ±15 deg/sec were not run. During these tests, there were indications that the fork in the pedal input mechanism had shifted during vibration with respect to the input lever. The fork and the operating shaft were pinned together as had been done for the suitability program on YG1143. The pedal input device was adjusted back to null with the lever centered, and the response tests were repeated. The system responses are shown in Figures C-1 and C-3 and the system performance after vibration is tabulated in Tables C-1 and C-2.

5.0 INSTRUMENTATION

The following instruments were used for the temperature and response tests:

- Bafco Frequency Response Analyzers 198-3801-002 and 198-3801-004
- Hewlett-Packard X-Y Plotter 827-0603-001
- Pressure Transducer, ±15 psi, 370-128 with Transducer Demodulator 760-093
- Flowmeter 420-079 and Electronic Counter 175-0527-001
- D.C. Power Supply 510-1933-001
- Test Gage, 100 psi, 360-007
- Pressure Gage, 600 psi, 360-0811-002
- Temperature Potentiometer 320-019
- Temperature Control Unit 589-548
- QE2 Flowbench
- Rotary Hydraulic Actuator

Additions for the vibration test include:

- Sanborn 4-channel Recorder 812-044 with dc Preamp 816-146
- Pressure Transducer, ±50 psi, 370-1601-004 with Transducer Demodulator 760-103
- Portable Flowbench SP-1
- Vibration Machine and Instrumentation

6.0 RECOMMENDATIONS

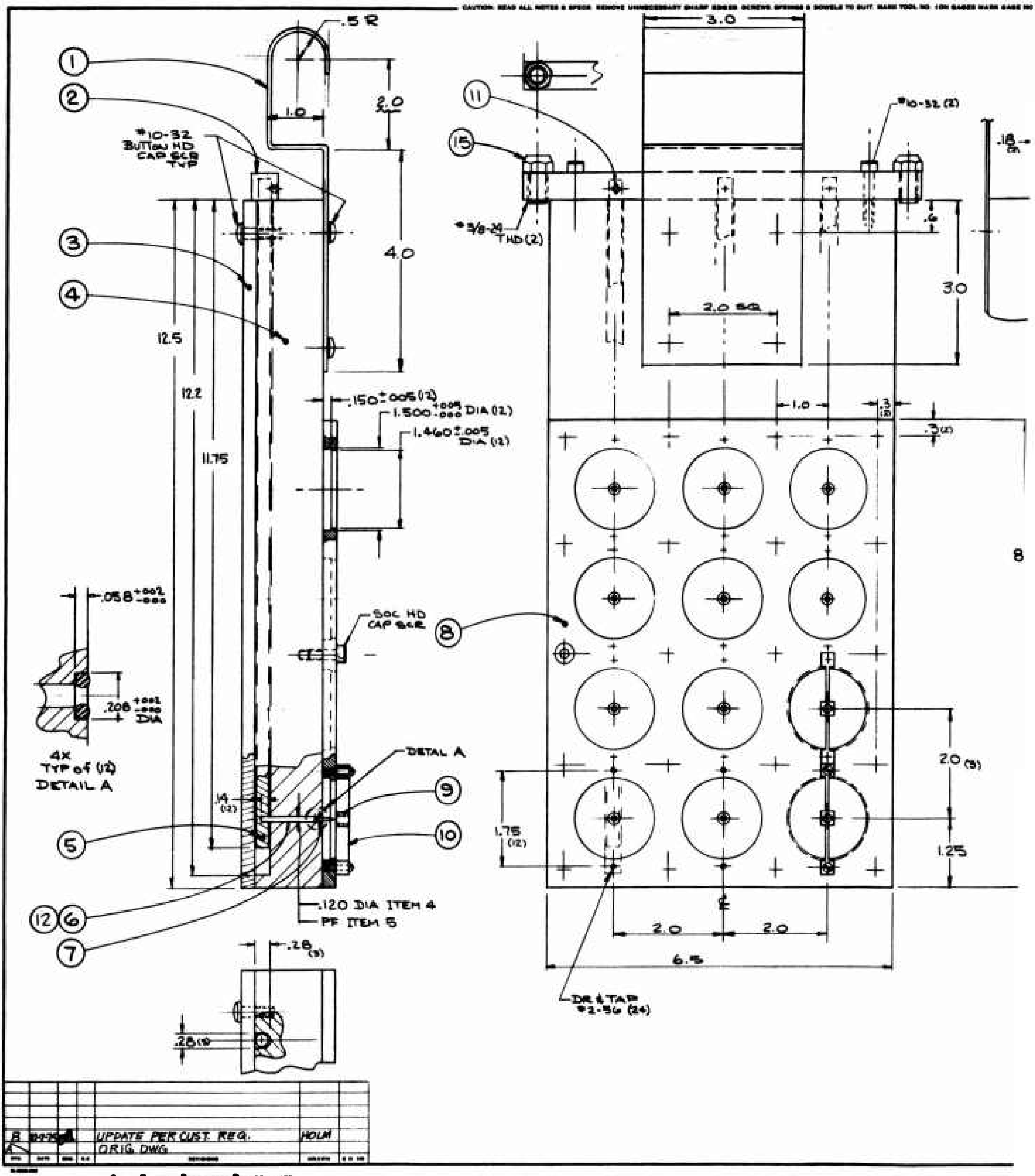
During the prequalification testing, the following changes were proposed:

- Add fixed standoffs to the manifold
- Change some passageways to equalize return pressure drops
- Improve "O"-ring seal configuration in feedback resistors.

A recommendation is made that additional development work be performed on a system with the proposed changes to reduce noise and temperature sensitivity. Areas to explore include flow and back pressures, feedback resistor configurations, and orifice sizes.

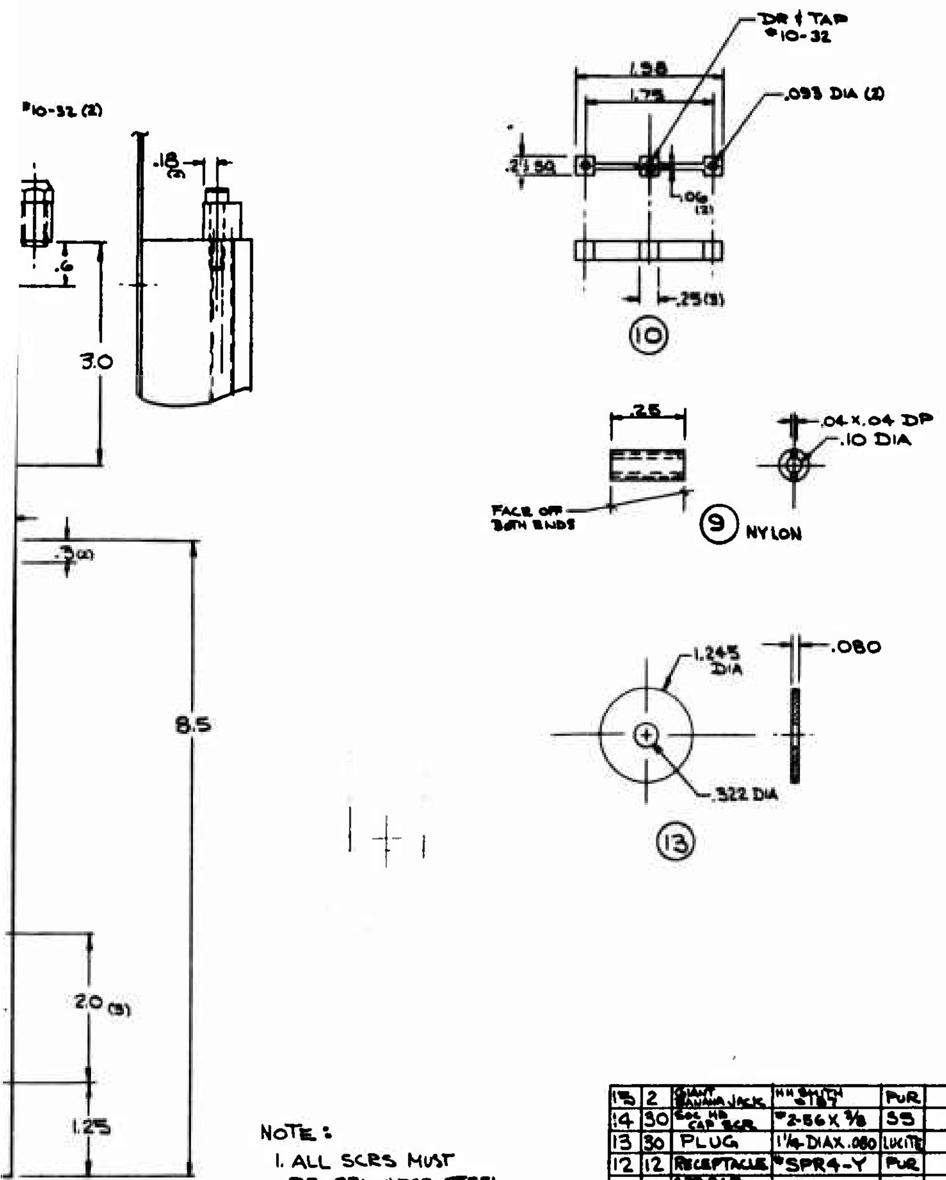
APPENDIX IV

PLATING FIXTURE AND TEST EQUIPMENT DRAWINGS



STRIVE TOWARD ERROR-FREE PERFORMANCE

TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY



NOTE :
1. ALL SCRS MUST BE STAINLESS STEEL

3 SPARE (items 10, 9)

DET	REQ	NAME	FINISHED SIZE	MAT'L	HEAT TO	MAT'L USED	WT. OR FT.	UNIT PRICE	TOTAL
15	2	GIANT BANANA JACK	HH SMITH #1187	PUR					
14	30	SOC HD CAP SCR	#2-56 X 3/8	SS					
13	30	PLUG	1 1/4 DIA X .080	LUCITE					
12	12	RECEPTACLE	#SPR4-Y	PUR		EVERETT CHARLES			
11	3	SET SCR CONE POINT	# 8-32	STK					
10	15	BAR	1/4 X 1/4 X 2	⟶		POLYPROPYLENE			
9	15	SCREW	#10-32 X 5/8 LG	NYLON					
8	1	TOP COVER	1/4 X 6 1/2 X 8 1/2	⟶		POLYPROPYLENE			
7	12	O'RING	MS28775-004	STK					
6	12	CONTACT	#SPA4-B	PUR		EVERETT CHARLES			
5	3	ROD	1/4 DIA X 12 3/8	COPPER		ALY BERYLLIUM COPPER			
4	1	BODY	1 1/4 X 6 1/2 X 12 1/2	LUCITE					
3	1	BOTTOM COVER	1/4 X 6 1/2 X 12 1/2	LUCITE					
2	1	BLOCK	1/2 X 1/2 X 7 1/2	BRASS					
1	1	HOOK	1/16 X 3 X 9	S.S.					

NOTE:
UNLESS OTHERWISE SPECIFIED:
BREAK UNNECESSARY SHARP CORNERS APPROXIMATELY 1/32".
SCREWS AND DOWELS TO SUIT.
STAMP A.I.S.I. TYPE OR BRAND NAME ON ALL TOOL STEEL ITEMS.
MAKE NO CHANGES IN DESIGN WITHOUT CONSULTING TOOL DESIGN DEPARTMENT.

MARK THE FOLLOWING INFORMATION ON NEW OR DUPLICATE ITEMS AS SHOWN ON THE TOOL ORDER:
PREFIX, TOOL NUMBER, COPY NUMBER, OWNING AGENCY
CUSTOMER TOOL NUMBER

HH-82

TOLERANCES UNLESS NOTED	DESIGNED FOR	PIECES	DATE 1974
MACH ± 0 1° FORMED ± 0°	DRAWN	RAY A	6 OCT
ONE PLACE DEC. ± 0.03	DETAILED		
TWO PLACE DEC. ± 0.010	CHECKED		
THREE PLACE DEC. ± 0.005	SUP'V.		
REF DWGS	ENG. SEC.	[illegible]	17 OCT

Honeywell

NAME VRS PLATING FIXTURE

PART — INSTR. YG1158

OP. — MACH. — E.O.

NO. SHEETS	SHEET NO.	SIZE	
1	1	D	YG 1158-T16

CHG. NO. ____ TOOL# ____ BIN ____ CHG. TO ____

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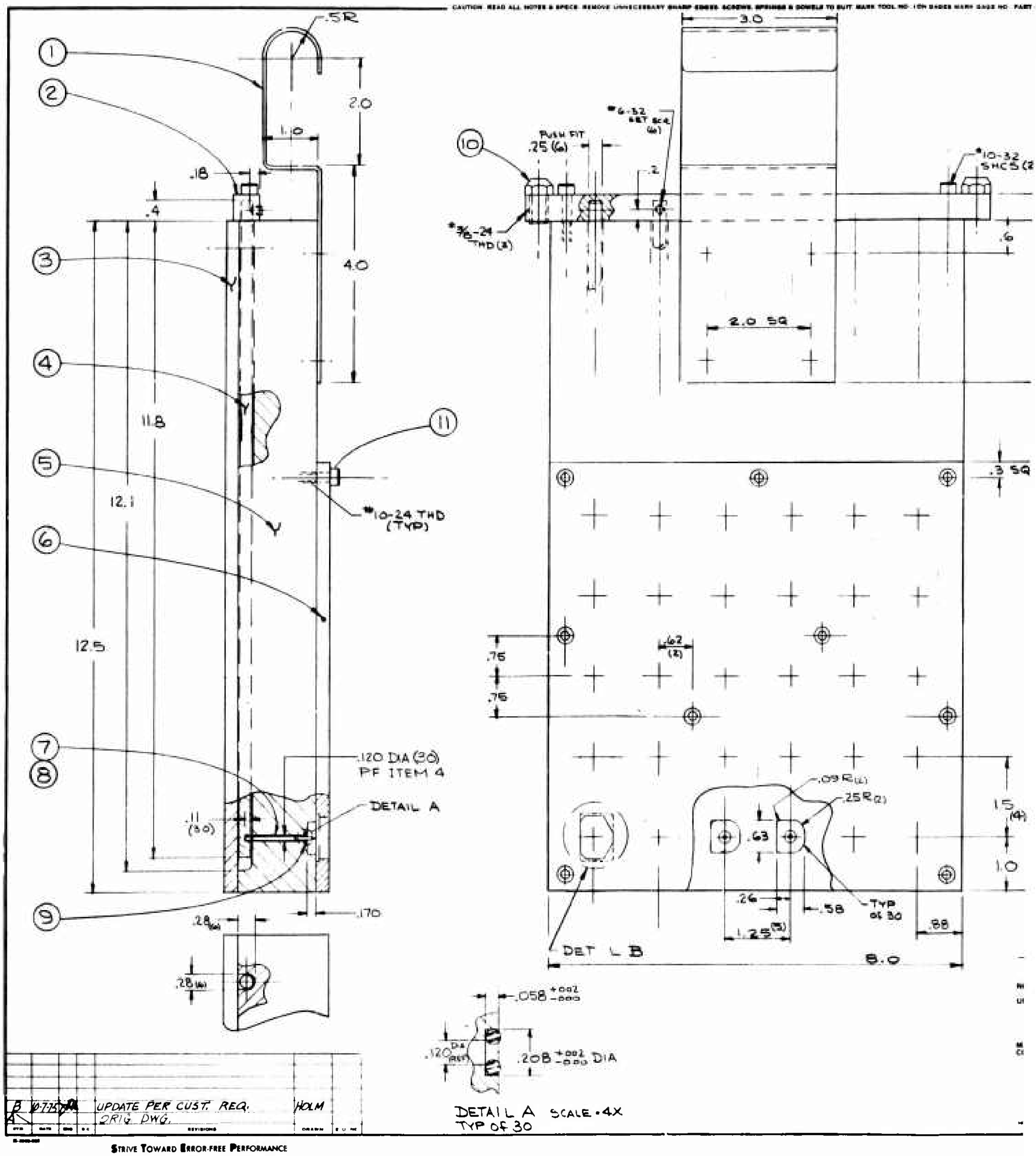
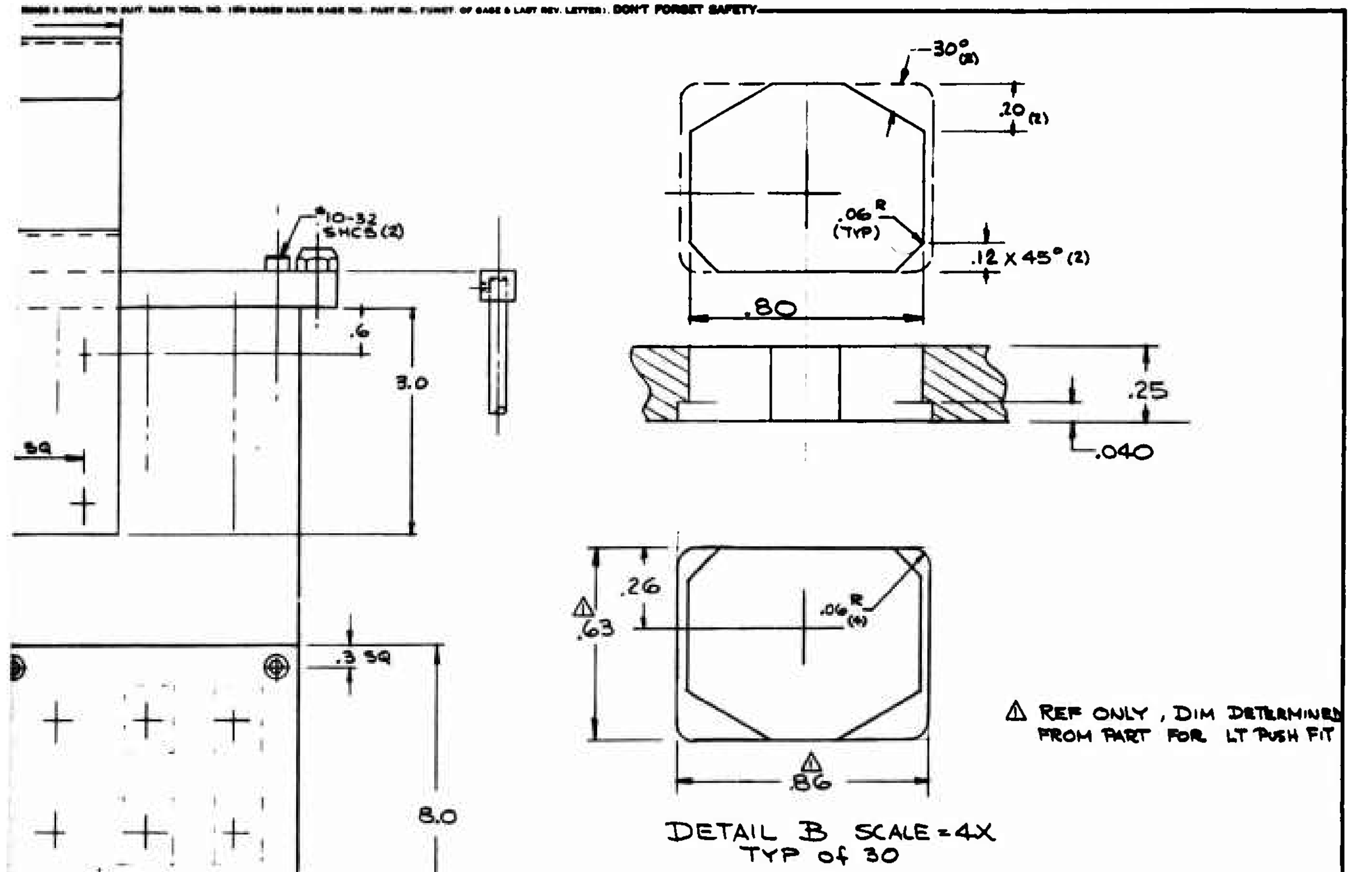
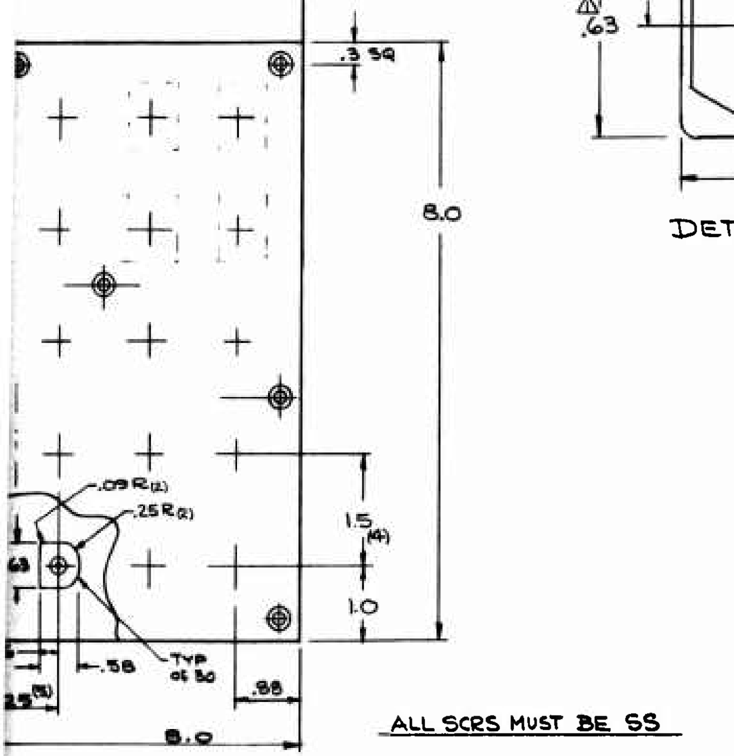


9

…DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO. PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY.





ALL SCRS MUST BE SS

DET	REQ	NAME	FINISHED SIZE	MAT'L	HEAT TO	MAT'L USED	WT OR FT	UNIT PRICE	TOTAL
11	10	SOC HD CAP SCR	#10-24 X ½ LG	SS					
10	2	GIANT BANANA JACK	#187			HH SMITH			
9	30	O' RING	MS28775-004	STK					
8	30	RECEPTACLE	SPR4-Y			EVERETT CHARLES			
7	30	CONTACT	SPA4-B			EVERETT CHARLES			
6	1	COVER	¼ X 8 X 8	→		POLYPROPYLENE			
5	1	BODY	1½ X 8 X 12½	LUCITE					
4	6	ROD	¼ DIA X 12¼	COPPER		ALT BERY COPPER			
3	1	COVER	¼ X 8 X 12½	LUCITE					
2	1	BLOCK	½ X ½ X 8	BRASS					
1	1	HOOK	1/16 X 3 X 8	[illegible]					

NOTE:

UNLESS OTHERWISE SPECIFIED:
BREAK UNNECESSARY SHARP CORNERS APPROXIMATELY 1/32".
SCREWS AND DOWELS TO SUIT.
STAMP A.I.S.I. TYPE OR BRAND NAME ON ALL TOOL STEEL ITEMS.
MAKE NO CHANGES IN DESIGN WITHOUT CONSULTING TOOL DESIGN DEPARTMENT.

MARK THE FOLLOWING INFORMATION ON NEW OR DUPLICATE ITEMS AS SHOWN ON THE TOOL ORDER:
PREFIX, TOOL NUMBER, COPY NUMBER, OWNING AGENCY
CUSTOMER TOOL NUMBER

HN-88

TOLERANCES UNLESS NOTED	DESIGNED FOR / PIECES	DATE 1974
MACH ± ½° FORMED ± 2°	DRAWN: FAY A	11 OCT
ONE PLACE DEC ± .030	DETAILED	
TWO PLACE DEC ± .010	CHECKED	
THREE PLACE DEC ± .005	SUP V.	
REF DWGS	ENG. SC	

Honeywell

NAME: RESISTOR PLATING FIXTURE
PART: 10050023 MODEL: YG 1158
OP. MACH. E.O.
NO. SHEETS: 1 SHEET NO.: 1 SIZE: D YG1158-T17

CHG NO ______ TOOL# ______ BIN ______ CHG. TO ______

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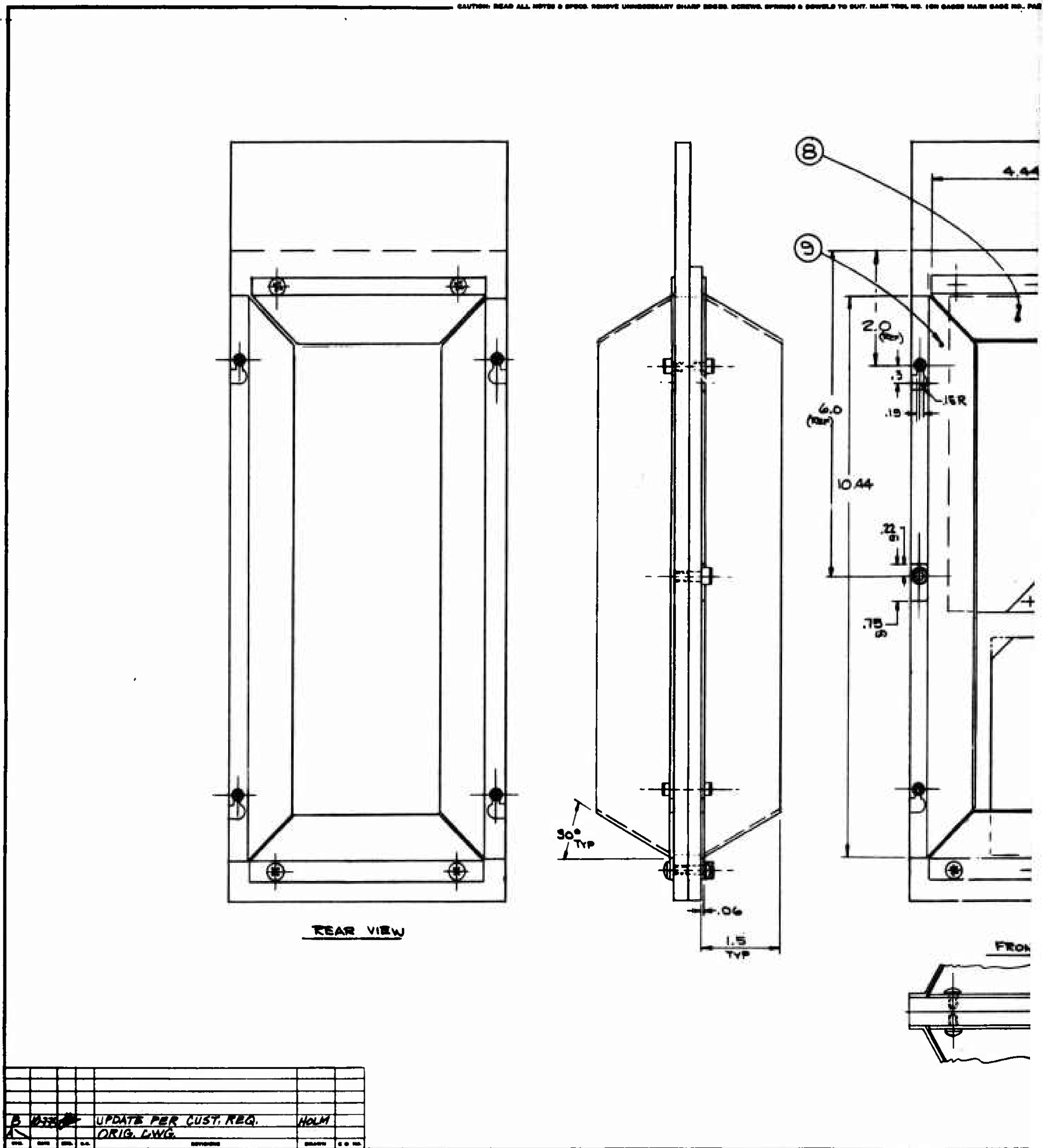
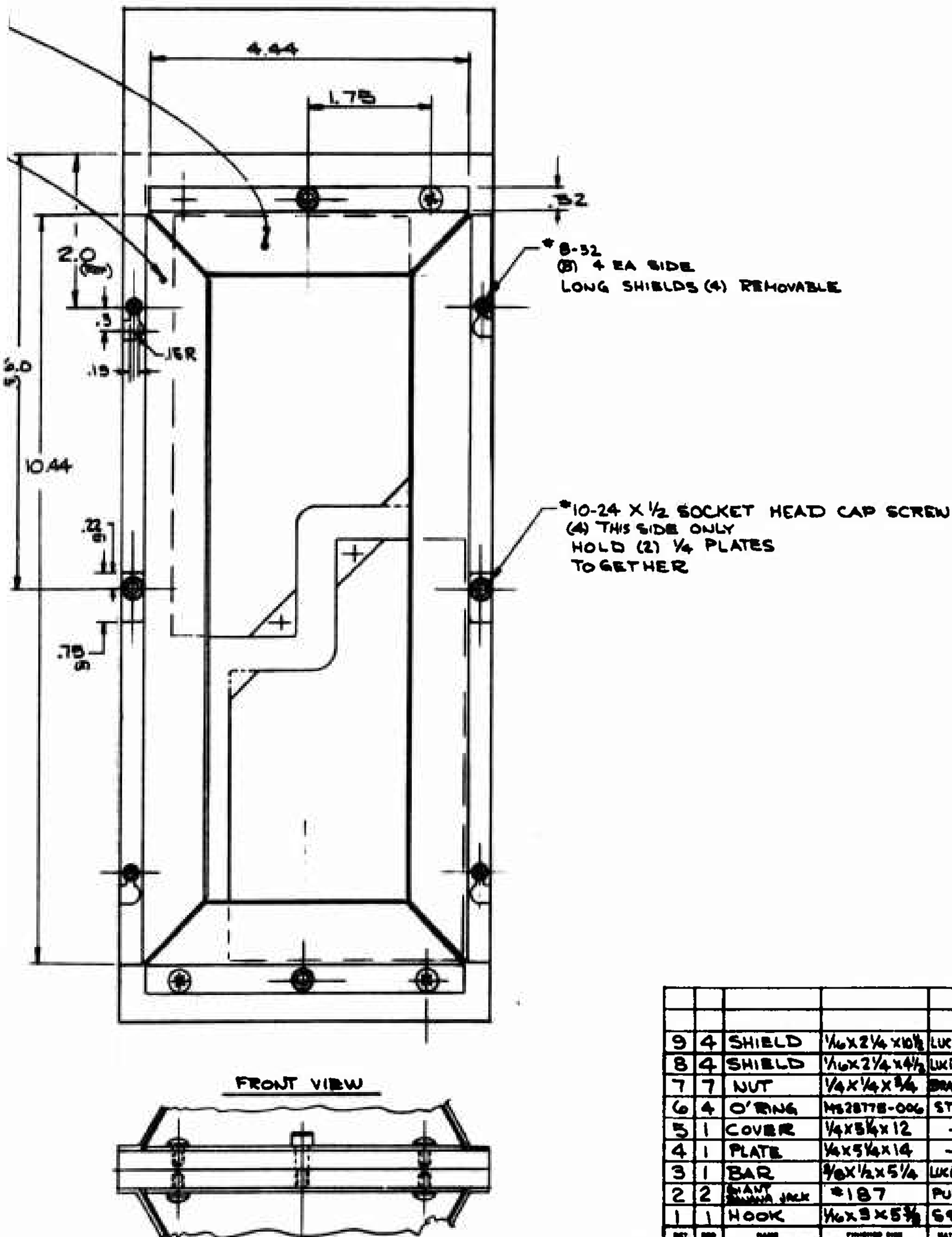


Strive Toward Error-free Performance

DON'T FORGET SAFETY



DET	REQ	NAME	FINISHED SIZE	MAT'L	HEAT TR	MAT'L USED	WT OR FT	UNIT PRICE	TOTAL
9	4	SHIELD	1/16 X 2 1/4 X 10 1/2	LUCITE					
8	4	SHIELD	1/16 X 2 1/4 X 4 1/2	LUCITE					
7	7	NUT	1/4 X 1/4 X 3/4	BRASS					
6	4	O'RING	MS28778-006	STK		SIZE 6			
5	1	COVER	1/4 X 5 1/4 X 12	⟶	⟶	POLYPROPYLENE			
4	1	PLATE	1/4 X 5 1/4 X 14	⟶	⟶	POLYPROPYLENE			
3	1	BAR	3/8 X 1/2 X 5 1/4	LUCITE					
2	2	GIANT BANANA JACK	#187	PUR		HH SMITH			
1	1	HOOK	1/16 X 3 X 5 3/8	SS					

TOLERANCES UNLESS NOTED	DESIGNED FOR	PIECES	DATE 1974
MACH ± 0°1' FORMED ± 0°2'	DRAWN	RAY A	BA CT
ONE PLACE DEC. ±0.5	DETAILED		
TWO PLACE DEC. ±0.015	CHECKED		
THREE PLACE DEC. ±0.005	SUP'V.		
	ENG. & C.		

Honeywell

NAME IC PLATING FIXTURE

PART 10030021 MOTR

OP. MACH. E.O.

NO. SHEETS	SHEET NO	SIZE	
2	1	D	YG1158-T18

10030021
REF DWGS.

CHG. NO. ____ TOOL # ____ BIN ____ CHG. TO ____

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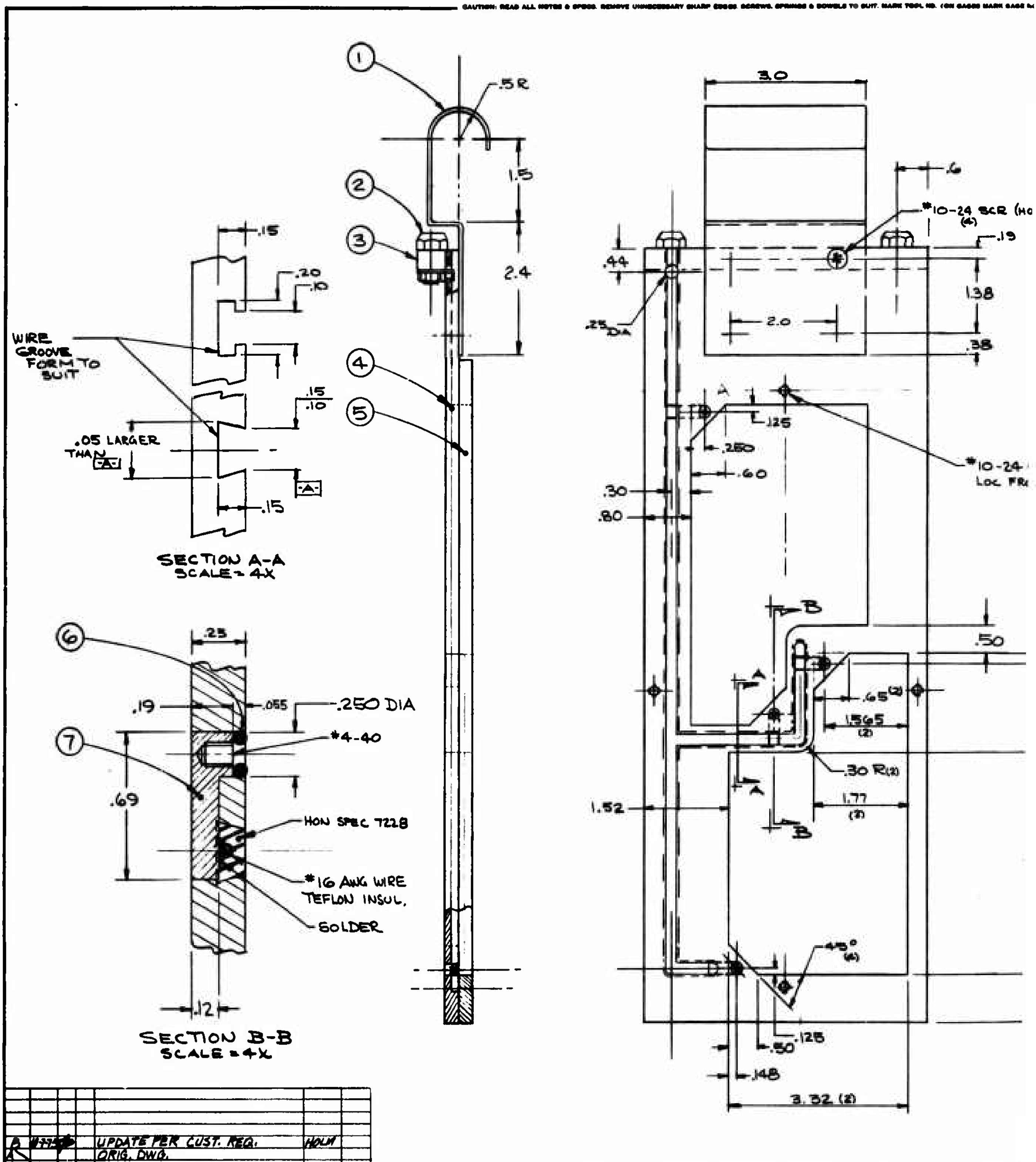
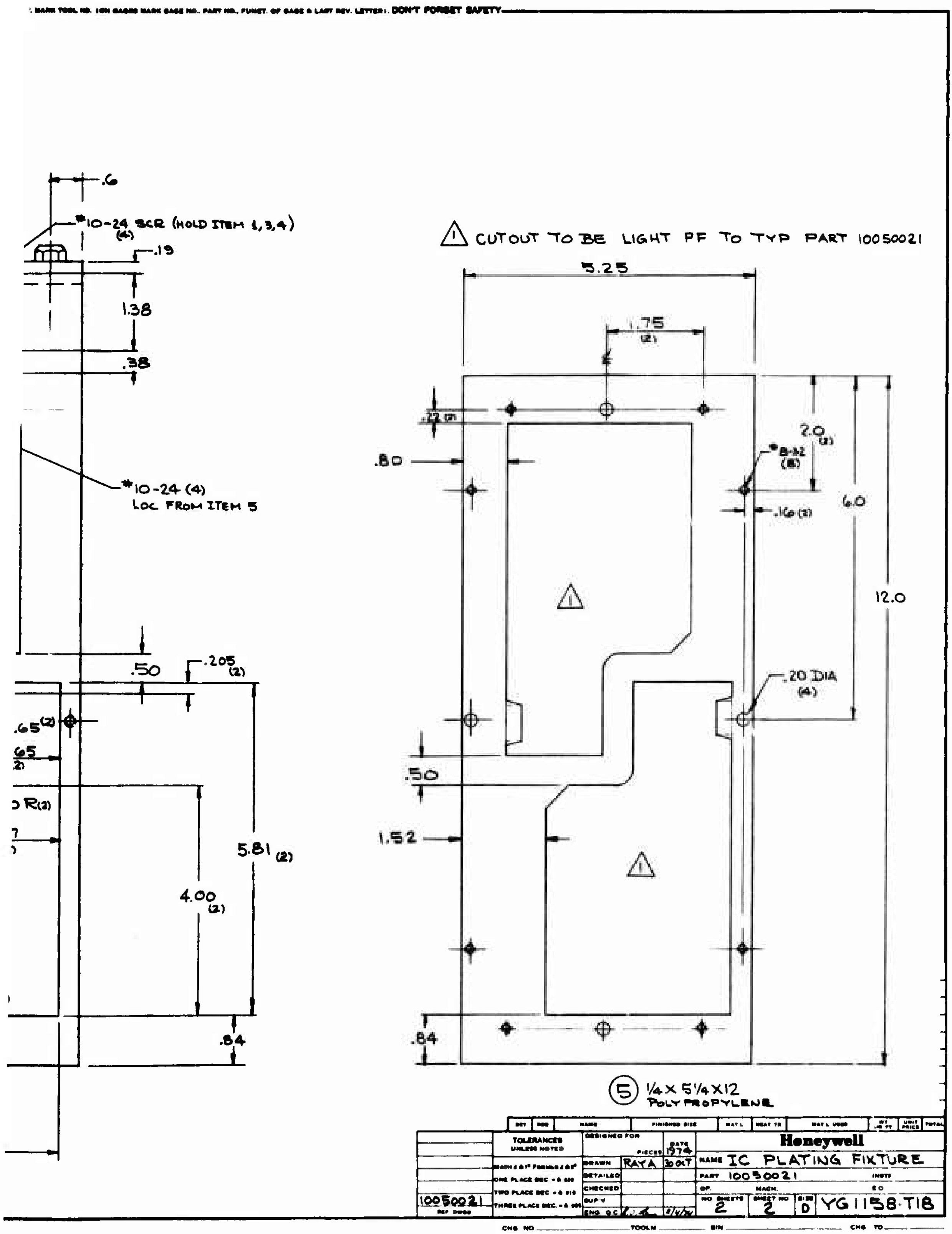


Strive Toward Error-free Performance


MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY
.6
*10-24 SCR (HOLD ITEM 1,3,4)
(4)
.19
1.38
.38
*10-24 (4)
LOC FROM ITEM 5
.50
.205
(2)
.65(2)
.65
(2)
R(2)
5.81 (2)
4.00
(2)
.84
CUTOUT TO BE LIGHT PF TO TYP PART 10050021
5.25
1.75
(2)
.72 (2)
.80
2.0
(2)
*8-32
(8)
.16 (2)
6.0
12.0
.20 DIA
(4)
.50
1.52
.84
5
1/4 X 5 1/4 X 12
POLY PROPYLENE
TOLERANCES UNLESS NOTED
DESIGNED FOR
DATE 1974
DRAWN RAYA 30 OCT
DETAILED
CHECKED
Honeywell
NAME IC PLATING FIXTURE
PART 10050021
NO. SHEETS 2
SHEET NO 2
SIZE D
YG1158-T18
10050021
CHG NO
TOOL N
BIN
CHG TO

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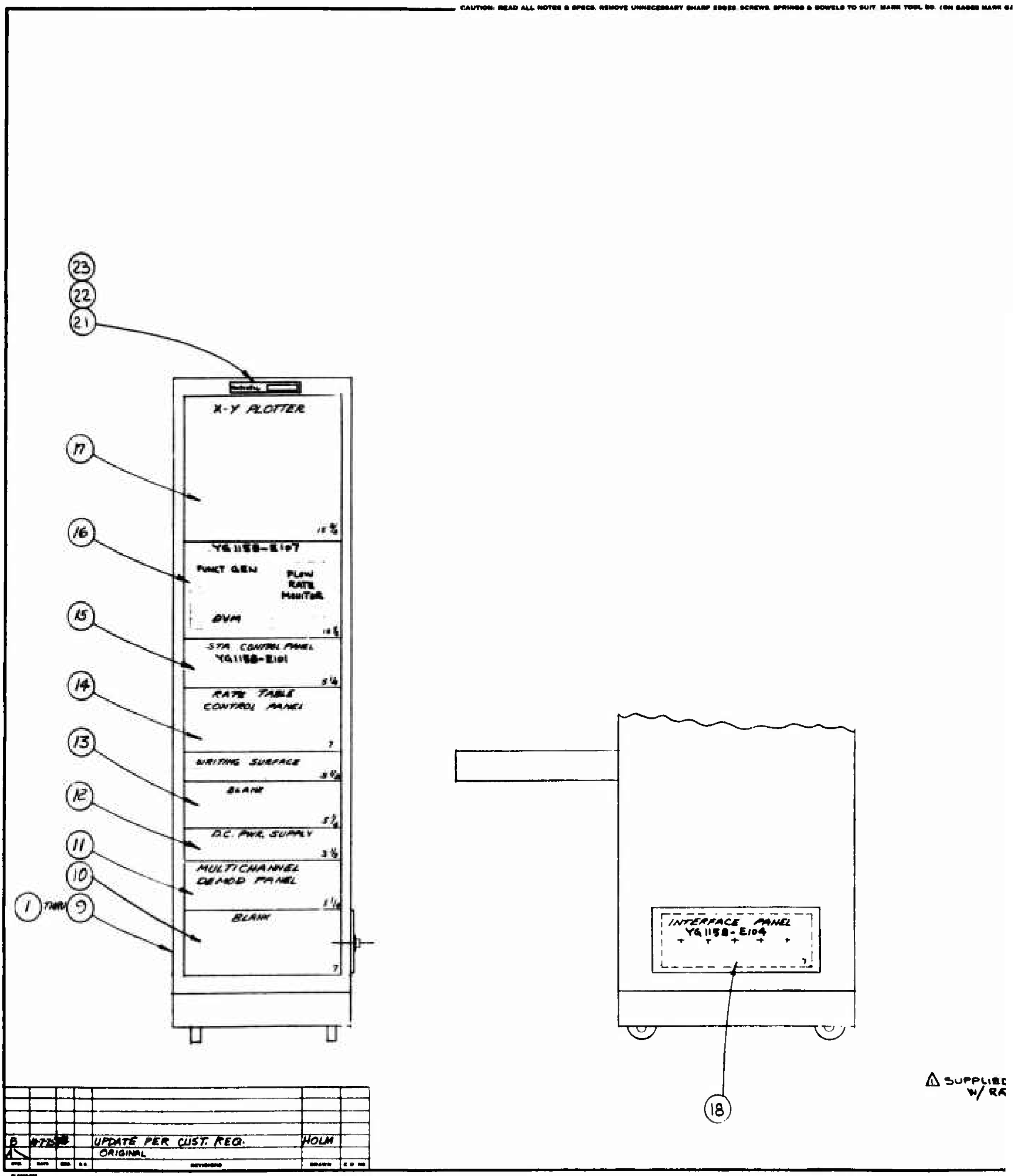


Strive Toward Error-free Performance

2

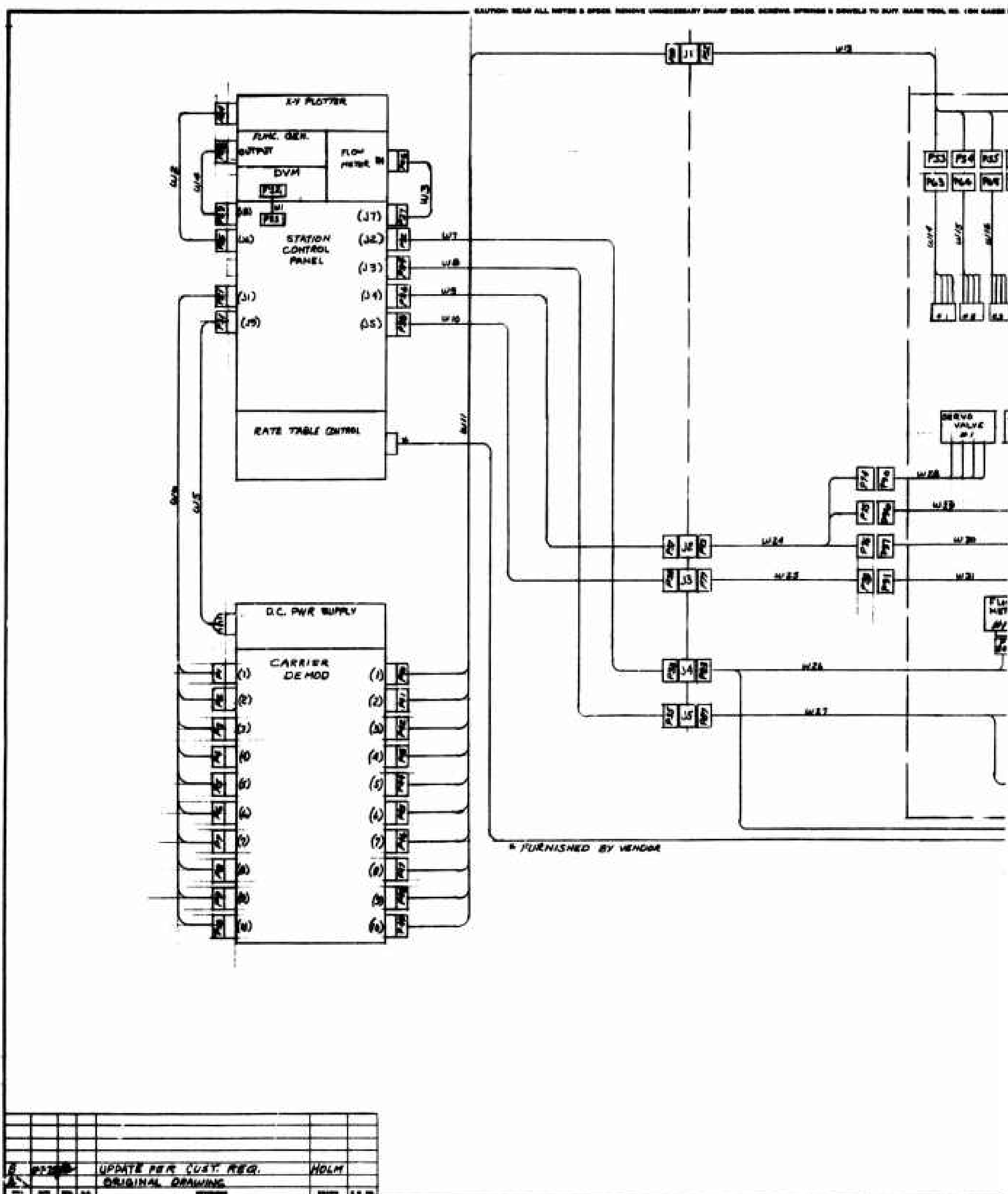
BUIT MARK TOOL NO (ON GAGES MARK GAGE NO. PART NO., FUNCT OF GAGE & LAST REV LETTER). DON'T FORGET SAFETY

P95	58	1	CONNECTOR	BENDIX # PT01A-8-4S (SR)	PUR
P93	57	1		MS3106A-28-21P (SR)	△
P92	56	1		BENDIX # PT06-8-4P (SR)	PUR
P91	55	1		BENDIX # PT01-14-5P (SR)	PUR
P86	54	1		MS3106A-28-21S (SR)	△
P84, 85, 94	53	3		MS3106A-10SL-4S	△
	52				
P28, 29	51	2		AMPH # 31-002	PUR
P27	50	1		BENDIX # PT06A-8-4S (SR)	PUR
P26	49	1		MS3106A-10SL-3S	△
P25	48	1		BENDIX # PT06A-12-10P (SR)	PUR
P22, 23	47	2	CONNECTOR	POMONA # 2970	PUR
P51	46		NOT USED		
P24	45	1	CONNECTOR	CINCH # DCM-37P	△
P78	44	1	CONNECTOR	BENDIX # PT06A-14-5S (SR)	PUR
P91 P96 P96 P63-P72	43	13	CONNECTOR	BENDIX # PT06A-8-4P (SR)	PUR
P53-P62 P74-P76	42	13	CONNECTOR	BENDIX # PT01A-8-4S (SR)	PUR
P52	41	1	CONNECTOR	BENDIX # PT06A-20-41P (SR)	PUR
P50	40	1	CONNECTOR	BENDIX # PT06A-20-41S (SR)	PUR
P40-P49	39	10	CONNECTOR	CANNON # WK4-21C	PUR
P31, 39	38	2	CONNECTOR	BENDIX # PT06A-14-5S (SR)	PUR
P38, P77	37	2	CONNECTOR	BENDIX # PT06A-14-5P (SR)	PUR
P35	36	1	CONNECTOR	BENDIX # PT06A-16-8S (SR)	PUR
P34, 87	35	2	CONNECTOR	BENDIX # PT06A-16-8P (SR)	PUR
P33, P37	34	2	CONNECTOR	BENDIX # PT06A-14-15S	PUR
P32, P36, P73, P83	33	4	CONNECTOR	BENDIX # PT06A-14-15P (SR)	PUR
P21	32	1	CONNECTOR	BENDIX # PT06A-20-39P (SR)	PUR
P11-P20	31		(NOT USED)		
P1-P10	30	10	CONNECTOR	CANNON # XLR-3-11C	PUR
	29	3	CLAMP	MS3057-12B	PUR
	28	15	CLAMP	MS3057-8B	PUR
	27	2	CLAMP	MS3057-10B	PUR
	26	26	CLAMP	MS3057-3B	PUR
	25				
	24				
	23	1	METAL LABEL	PER SHT 6	
	22	2	CLIP	HON 10023544-101	
	21	1	IDENT PLATE	HON 10023543	
	20				
	19				
	18	1	INTERFACE PANEL	YG 1158-E104	
	17	1	X-Y PLOTTER	HEWLETT-PACKARD MODEL # 7044A, OPTION 001, 007 REAR CONN. 120V 60HZ. 1300	
	16	1	INSTRUMENT PANEL	YG 1158-E107	
	15	1	STA. CONTROL PANEL	YG 1158-E101	
	14		RATE TABLE CONTROL PANEL	AEROTECH # ART 100-1	
	13	1	BLANK PANEL		5¼
	12	1	D.C. POWER SUPPLY	HEWLETT PACKARD #6289A	
	11	1	MULTICHANNEL DEMOD PANEL	VALIDYNE # MC 1-10	
	10	1	BLANK PANEL		7"
	9		POWER STRIP	WABER # 705CB-15	
	8				
	7	1	CABINET FRAME	HONEYWELL # 41H19	
	6	1	BOT PANEL	# 19PG	
	5	1	L. SIDE PANEL	# H5LK	
	4	1	R. SIDE PANEL	# F9RK	
	3	1	ANTI-TILT BASE	# AT819-25-4	
	2	1	REAR DOOR	# H1AW	
	1	1	CABINET WRITING SURF.	HONEYWELL # WS519-25-1	
	DET	QTY	NAME		

△ SUPPLIED BY VENDER W/ RATE TABLE

TOLERANCES UNLESS NOTED	DESIGNED FOR		**Honeywell**
	PIECES	1974	NAME FLUIDICS TEST STATION
	DRAWN	HOLM 9-15	PART
ONE PLACE DEC ± 0.030	DETAILED		OP / MACH
TWO PLACE DEC ± 0.010	CHECKED		NO SHEETS 6 / SHEET NO 1 / SIZE D
THREE PLACE DEC ± 0.005	SUP V / ENG Q C		YG1158-E100

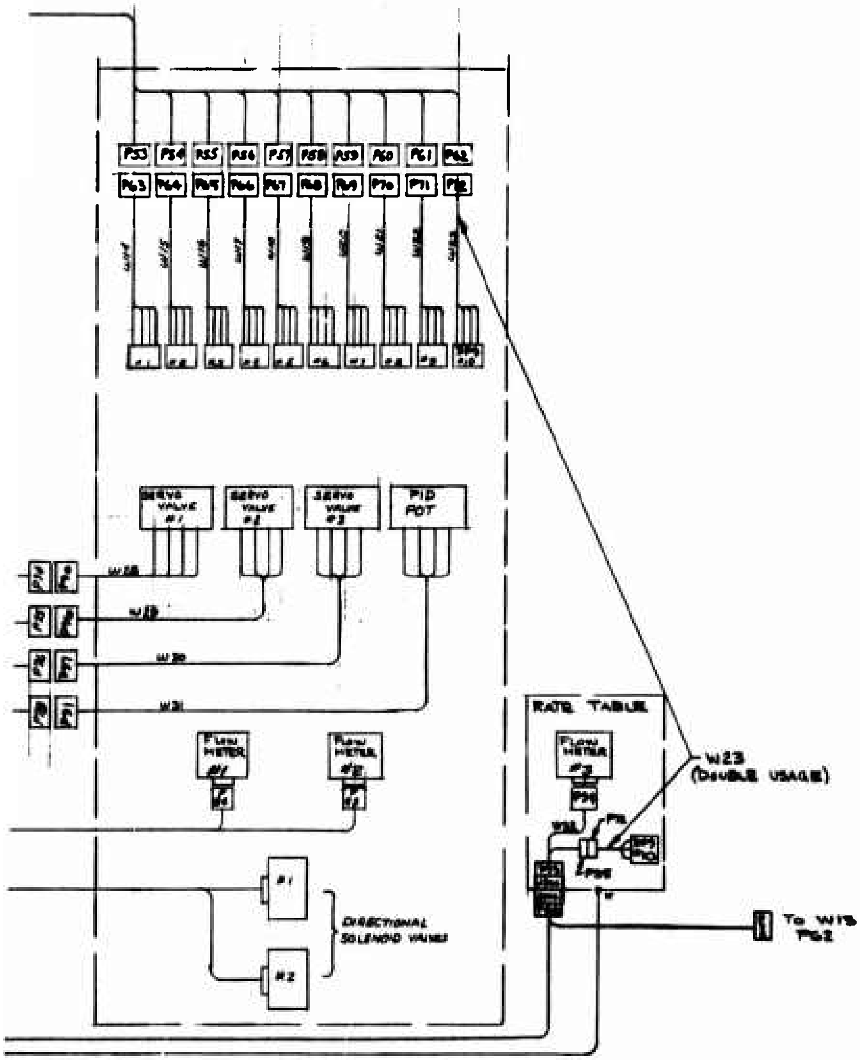
CHG NO ______ TOOL ______ BIN ______ CHG TO ______



Strive Toward Error-free Performance

2

LO TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY



TOLERANCES UNLESS NOTED	DESIGNED FOR	Honeywell
	DATE 1973	NAME FLUIDICS TEST STATION
	DRAWN HOLM 9-17	PART
ONE PLACE DEC.	DETAILED	OP. MACH. E.O.
TWO PLACE DEC. ±.010	CHECKED	NO. SHEETS 6
THREE PLACE DEC.	SUPV.	SHEET NO. 2
REF DWGS.	ENG.	SIZE D YG 1158-E100

CHG. NO. TOOLM. DN. CHG. TO

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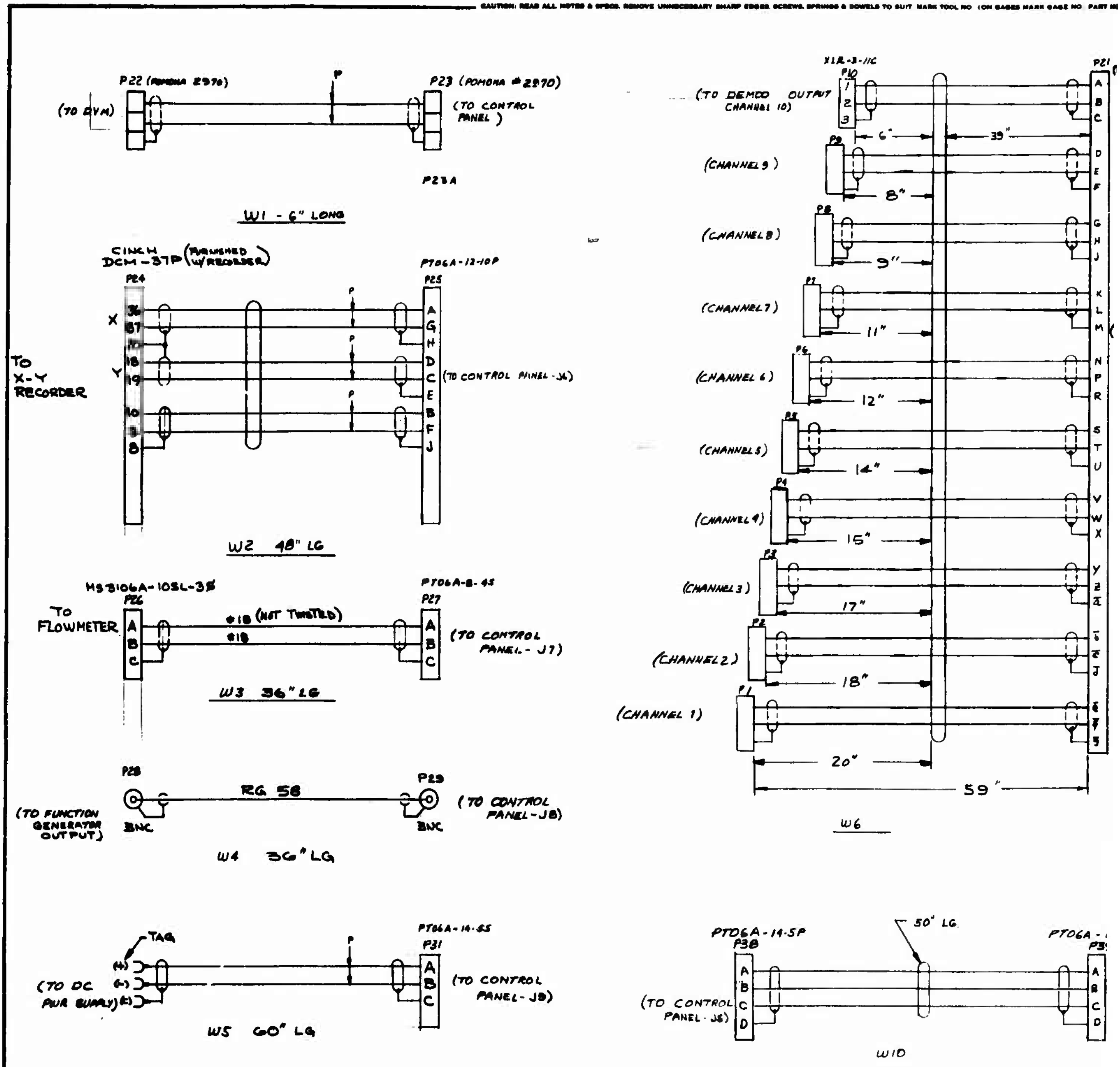


3) ENCLOSE WIRES IN EXTRUDED PLASTIC TUBING TO SUIT

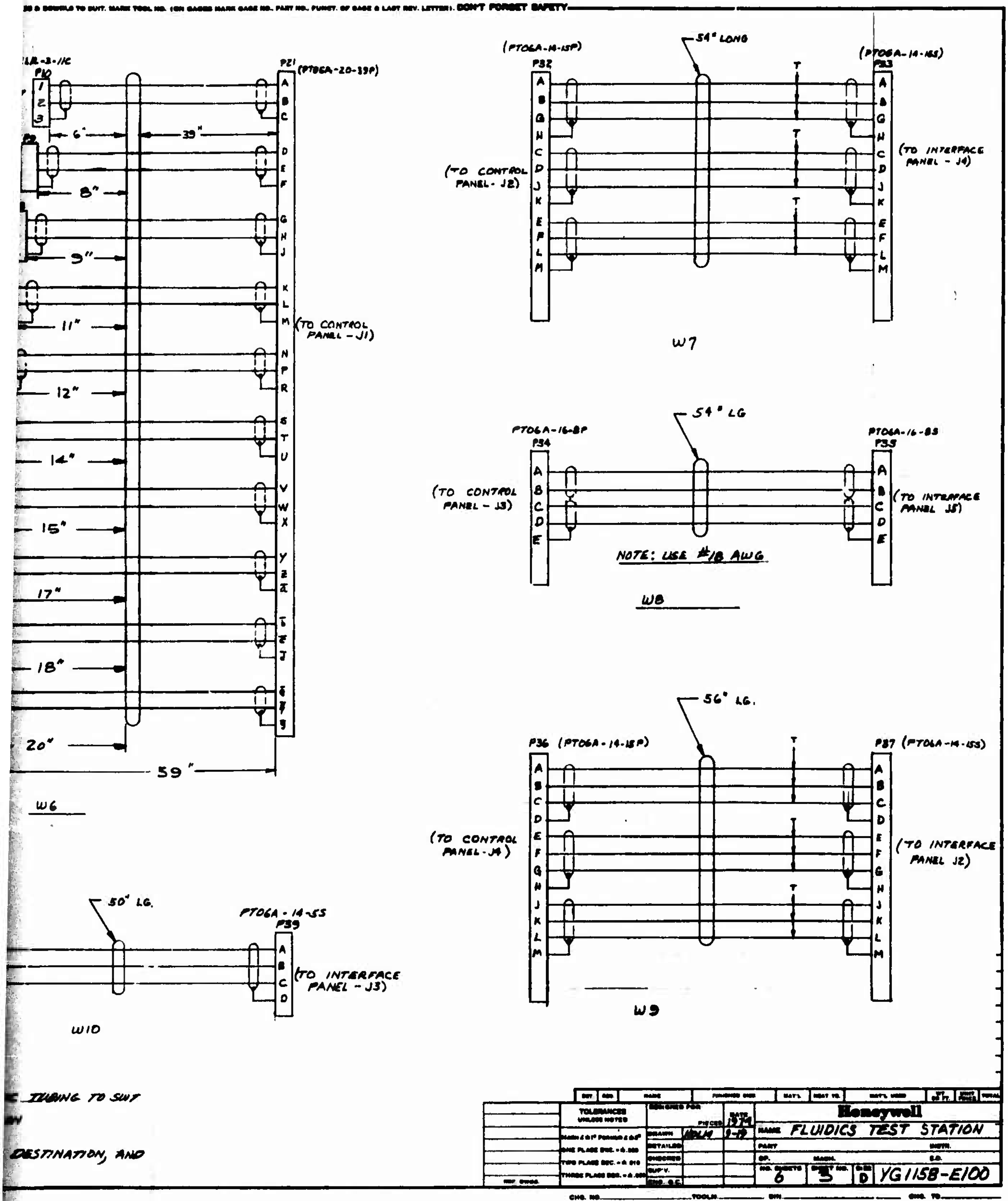
2) ALL LEAD WIRE TO BE AWG #22 TEFLON INSULATED UNLESS NOTED.

1.) MARK TAG WITH CABLE NO., TOOL NO., & DESTINATION, AND ATTACH TO CABLE TO SUIT.

B	UPDATE PER CUST. REQ.	HOLM
A	ORIGINAL DRAWING	

STRIVE TOWARD ERROR-FREE PERFORMANCE

2


DON'T FORGET SAFETY
P10
P21 (PT06A-20-39P)
6"
39"
8"
9"
11"
12"
14"
15"
17"
18"
20"
59"
(TO CONTROL PANEL - J1)
W6
(PT06A-14-15P)
P32
54" LONG
(PT06A-14-16S)
P33
(TO CONTROL PANEL - J2)
(TO INTERFACE PANEL - J4)
W7
PT06A-16-8P
P34
54" LG
PT06A-16-8S
P35
(TO CONTROL PANEL - J3)
(TO INTERFACE PANEL J5)
NOTE: USE #18 AWG
W8
56" LG.
P36 (PT06A-14-18P)
P37 (PT06A-14-15S)
(TO CONTROL PANEL - J4)
(TO INTERFACE PANEL J2)
W9
50" LG.
PT06A-14-5S
P39
(TO INTERFACE PANEL - J3)
W10
TUBING TO SUIT
DESTINATION, AND
TOLERANCES UNLESS NOTED
Honeywell
NAME FLUIDICS TEST STATION
6
3
D
YG115B-E100

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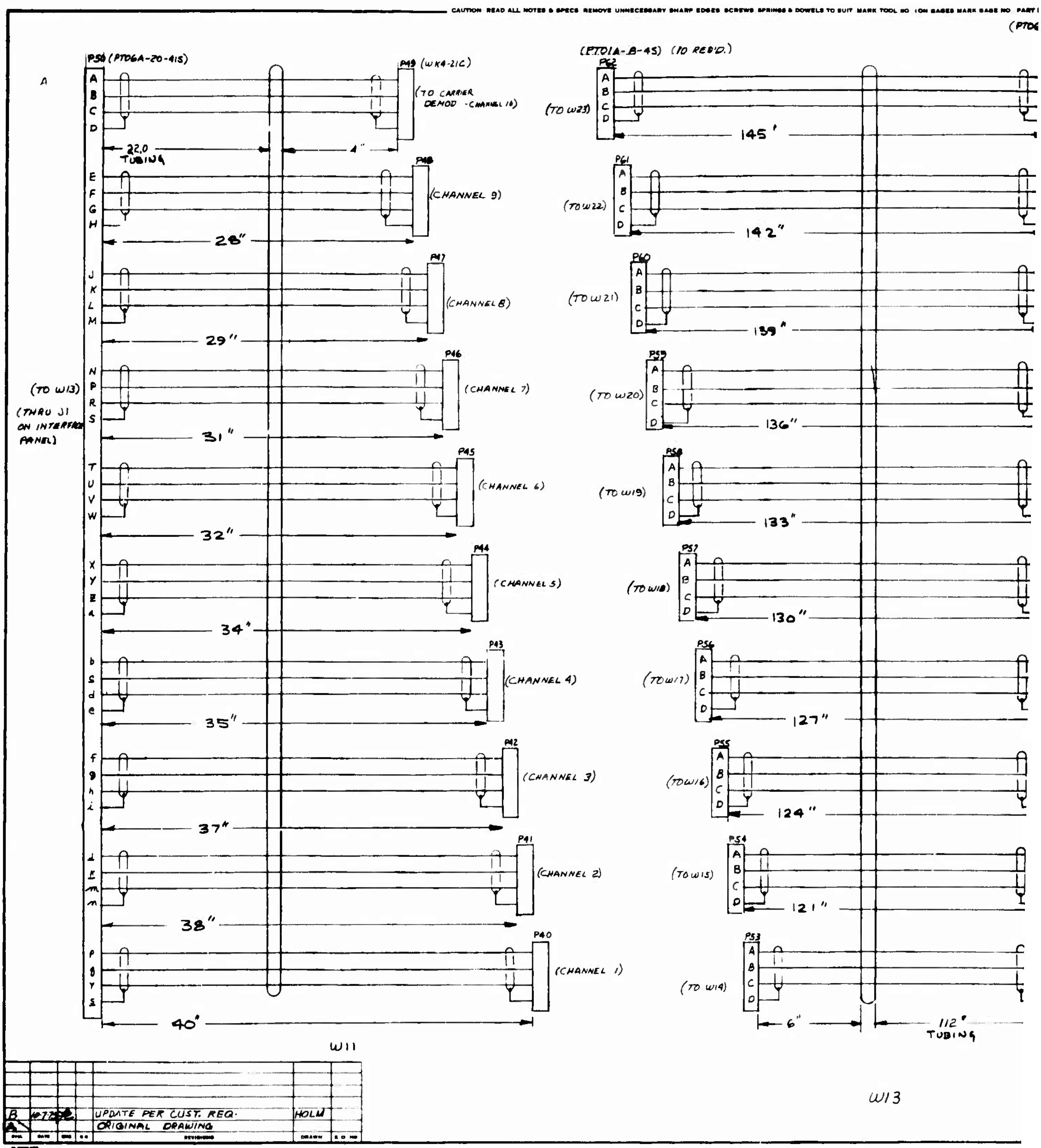
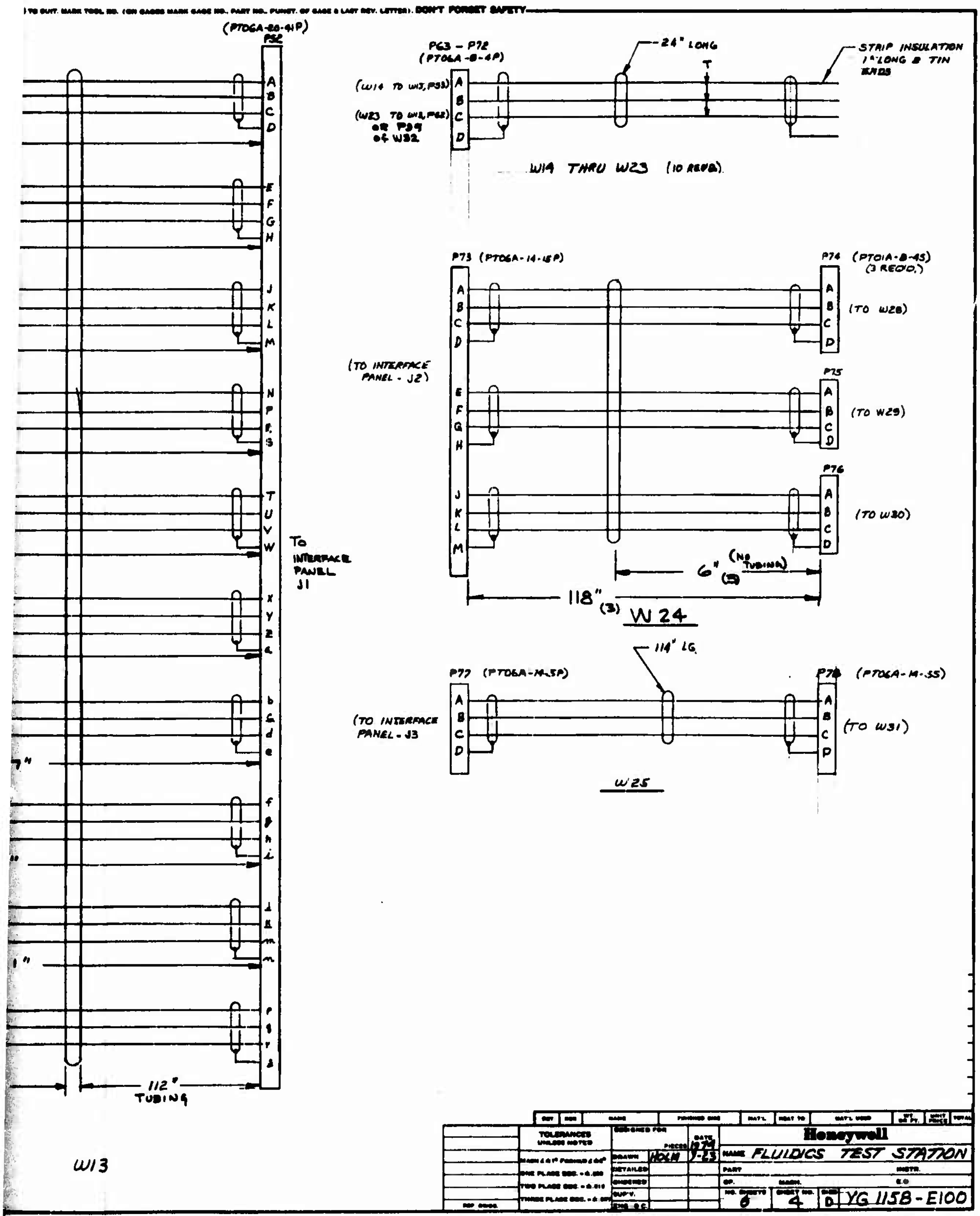
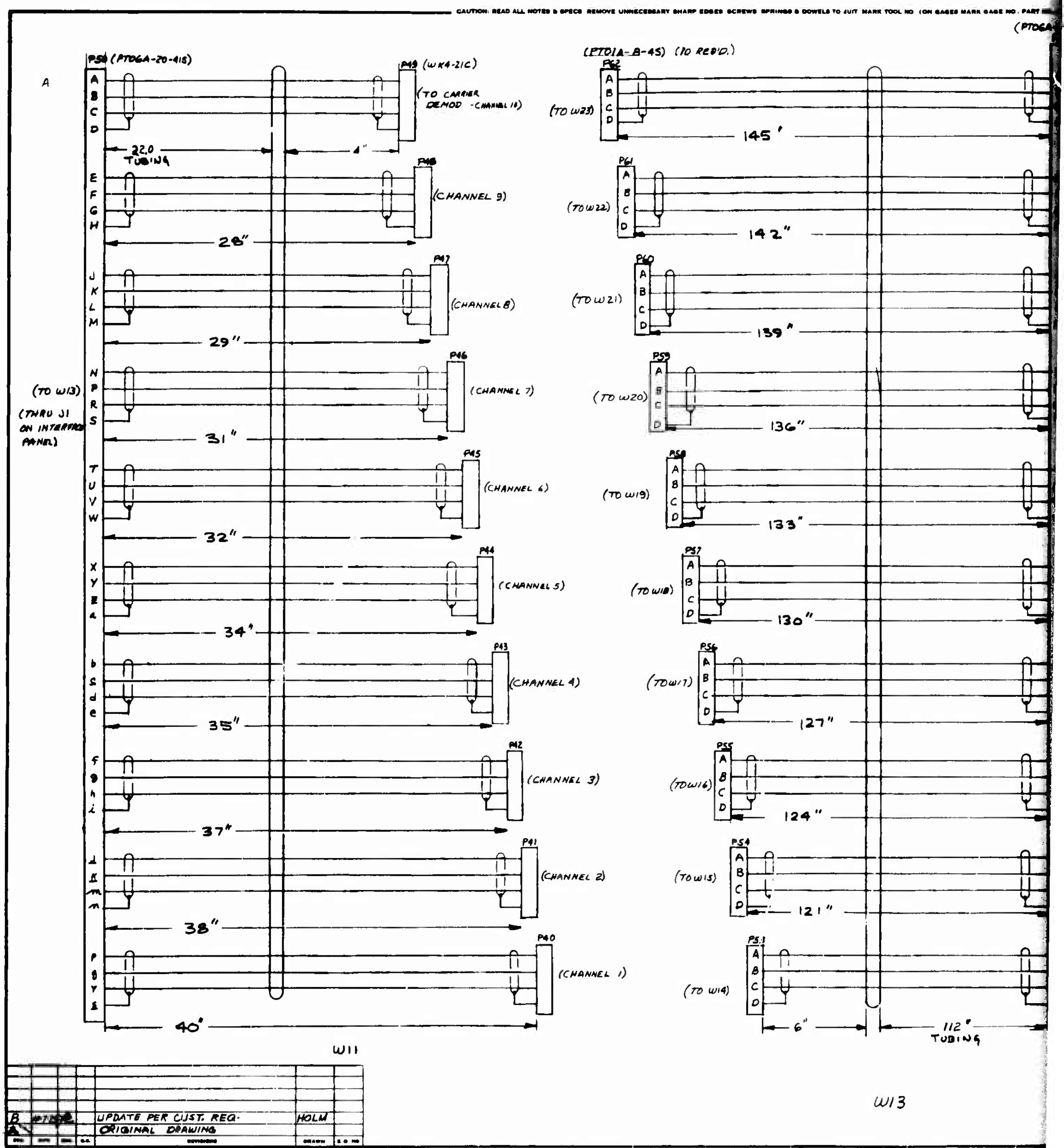


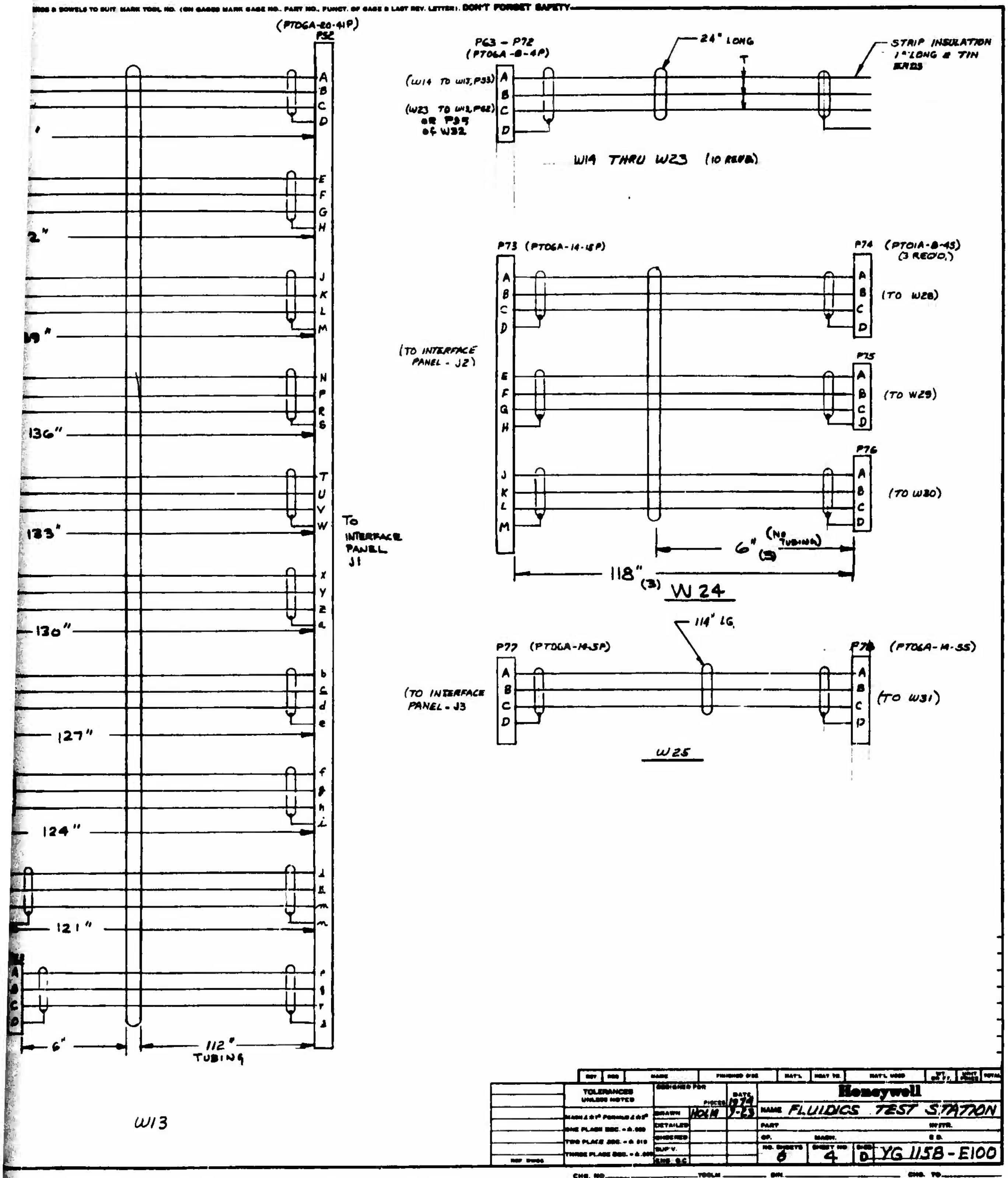
Strive Toward Error-free Performance

2

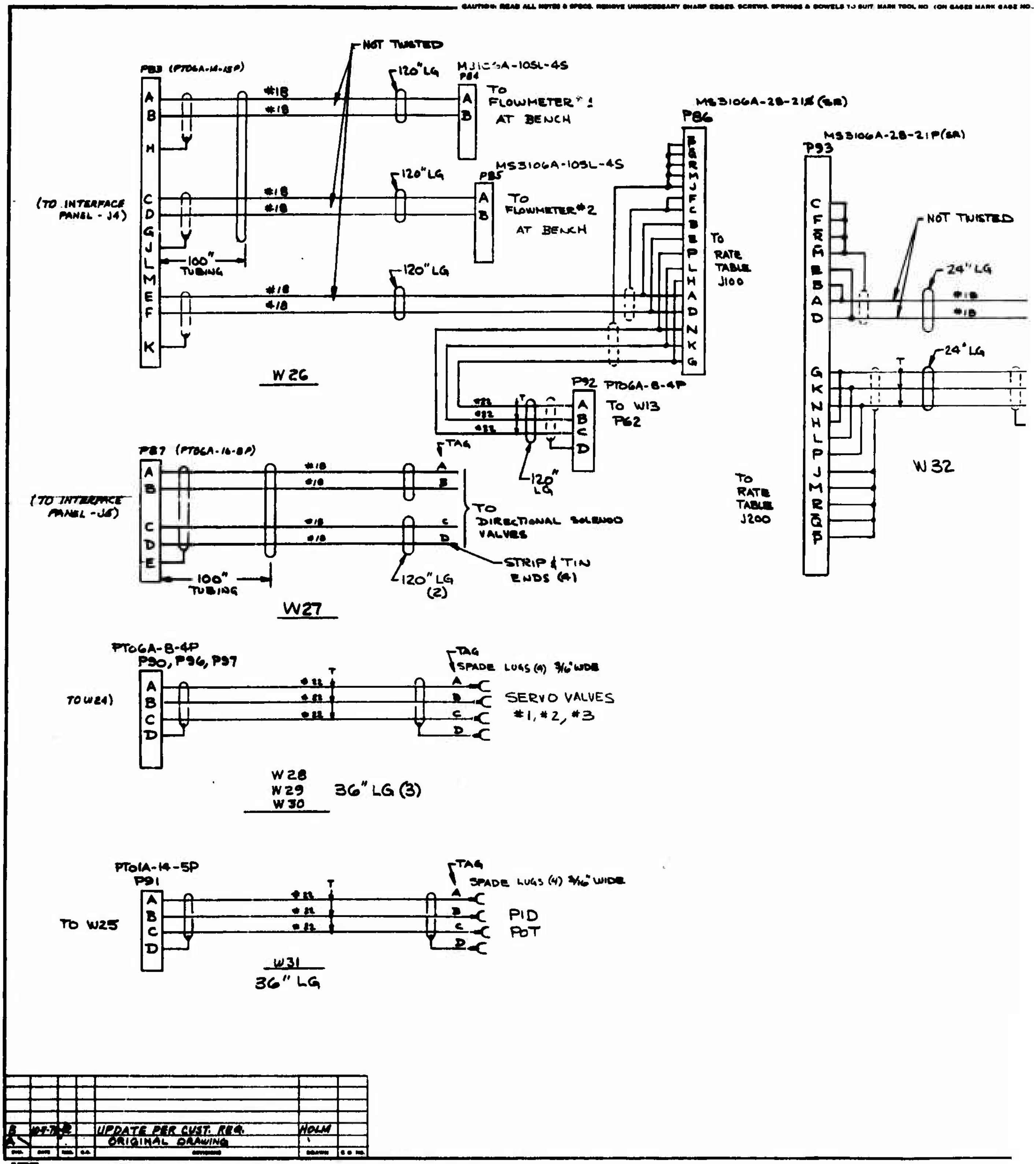

DON'T FORGET SAFETY
(PTO6A-20-41P)
P52
TO INTERFACE PANEL J1
112" TUBING
W13
P63 - P72
(PTO6A-8-4P)
(W14 TO W3, P53)
(W23 TO W3, P62) OR P39 OF W32
24" LONG
STRIP INSULATION 1" LONG & TIN ENDS
W14 THRU W23 (10 REQD.)
P73 (PTO6A-14-15P)
P74 (PTO1A-8-4S) (3 REQD.)
(TO W28)
(TO INTERFACE PANEL - J2)
P75
(TO W29)
P76
(TO W30)
6" (NO TUBING)
118"
W 24
114" LG.
P77 (PTO6A-14-5P)
P78 (PTO6A-14-5S)
(TO INTERFACE PANEL - J3)
(TO W31)
W25
TOLERANCES UNLESS NOTED
DRAWN HOLM 9-23
Honeywell
NAME FLUIDICS TEST STATION
6
4
D
YG 115B-E100


CAUTION: READ ALL NOTES & SPECS REMOVE UNNECESSARY SHARP EDGES SCREWS SPRINGS & DOWELS TO SUIT MARK TOOL NO (ON GAGES MARK GAGE NO. PART
P50 (PT06A-20-41S)
P49 (WK4-21C)
(TO CARRIER DEMOD -CHANNEL 10)
22.0 TUBING
4"
P48 (CHANNEL 9)
28"
P47 (CHANNEL 8)
29"
(TO W13)
(THRU J1 ON INTERFACE PANEL)
P46 (CHANNEL 7)
31"
P45 (CHANNEL 6)
32"
P44 (CHANNEL 5)
34"
P43 (CHANNEL 4)
35"
P42 (CHANNEL 3)
37"
P41 (CHANNEL 2)
38"
P40 (CHANNEL 1)
40"
(PT01A-8-4S) (10 REQ'D.)
P62 (TO W23) 145"
P61 (TO W22) 142"
P60 (TO W21) 139"
P59 (TO W20) 136"
P58 (TO W19) 133"
P57 (TO W18) 130"
P56 (TO W17) 127"
P55 (TO W16) 124"
P54 (TO W15) 121"
P53 (TO W14)
6"
112" TUBING
W11
W13
B UPDATE PER CUST. REQ. HOLM
A ORIGINAL DRAWING

2



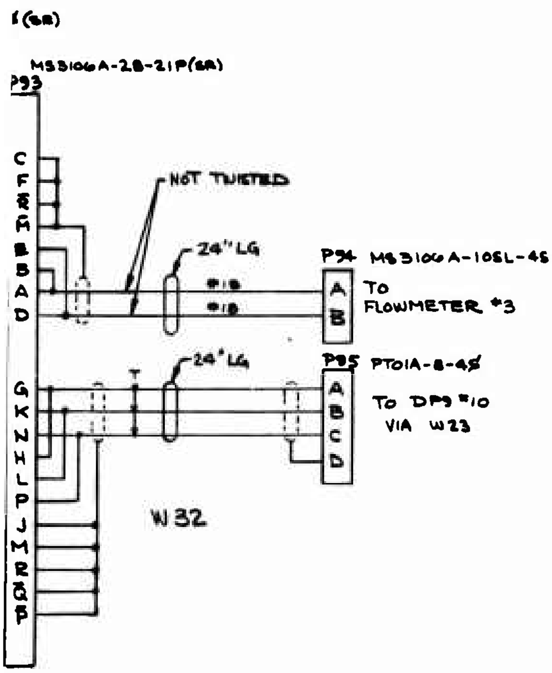
DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY.
(PT06A-20-41P)
P52
To INTERFACE PANEL J1
136"
133"
130"
127"
124"
121"
6"
112" TUBING
W13
P63 - P72
(PT06A-8-4P)
(W14 TO W17, P53)
(W23 TO W12, P62) OR P59 OF W32
24" LONG
STRIP INSULATION 1" LONG & TIN ENDS
W14 THRU W23 (10 REQD)
P73 (PT06A-14-18P)
P74 (PT01A-8-4S) (3 REQD.)
(TO W28)
P75
(TO W29)
P76
(TO W30)
(TO INTERFACE PANEL - J2)
6" (5) (NO TUBING)
118" (3)
W 24
114" LG.
P77 (PT06A-14-5P)
P78 (PT06A-14-5S)
(TO INTERFACE PANEL - J3
(TO W31)
W25
Honeywell
NAME FLUIDICS TEST STATION
DRAWN HOLM 1974 7-23
6
4
D
YG 115B - E100



STRIVE TOWARD ERROR-FREE PERFORMANCE

2

DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO. PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY



TOLERANCES UNLESS NOTED

DESIGNED FOR

DRAWN HOLM 9-26 1979

Honeywell

NAME FLUIDICS TEST STATION

NO. SHEETS 6 SHEET NO. 5 DISC D YG 115B-E100

CHG. NO. TOOL DIR CHG. TO

DON'T FORGET SAFETY — MARK TOOL NO. YG 1158-E100

YG1158 E100
FLUIDICS TEST STATION

MAKE METAL LABEL
BLACK LETTERS

ACCT. NO. — BIN — TOOLM. — CHG. NO.

SYM	DATE	ORIG	REVISIONS	EO / DWN
B	10-75		UPDATE PER CUST. REQ.	HOLM
A			ORIG. DWG	

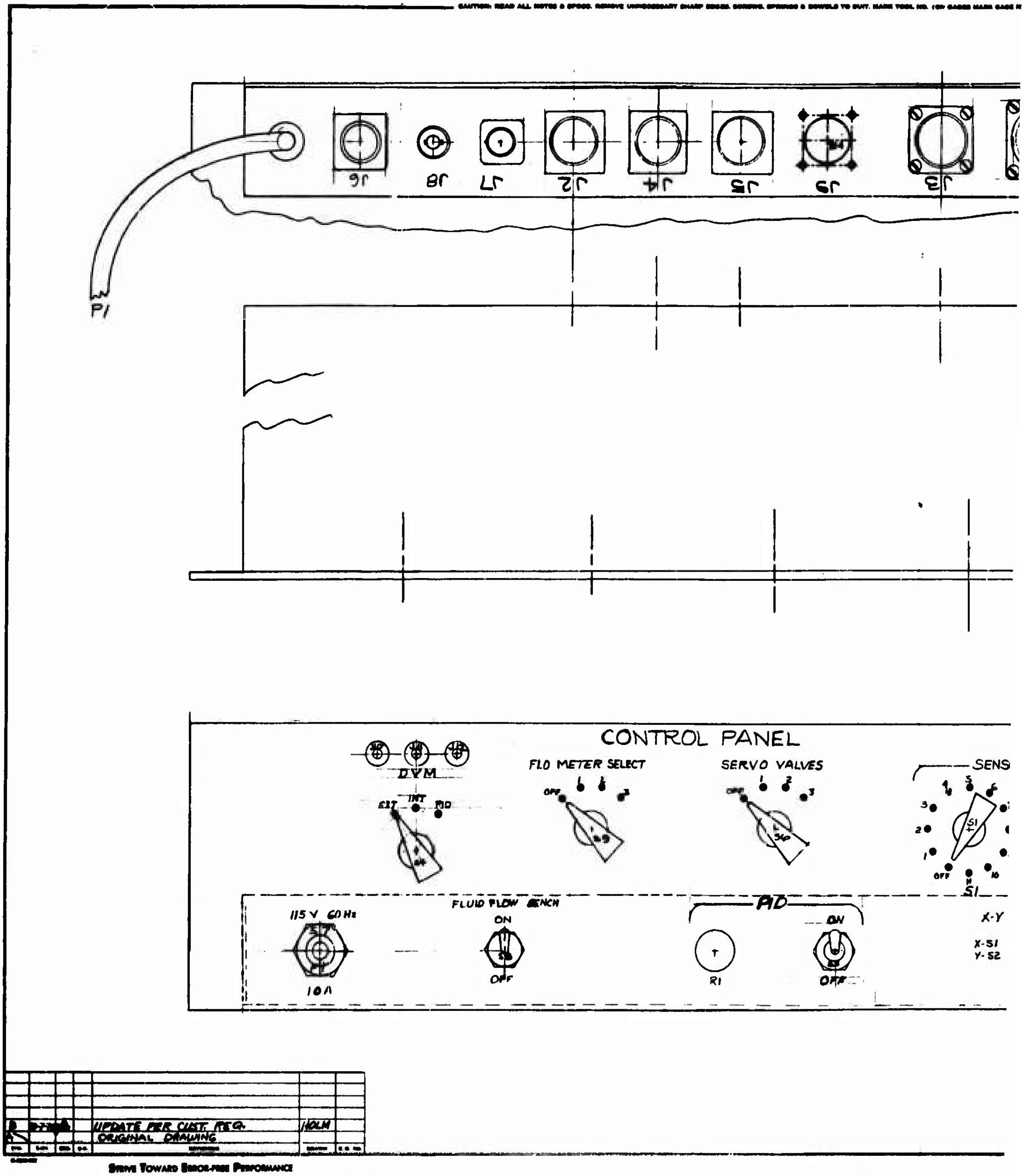
REF. DWGS.	TOLERANCES UNLESS NOTED	DESIGNED FOR	PIECES	DATE 1974
	MACH ∠ ±1° FORMED ∠ ±2°	DRAWN	RAY A	21 SEPT
	ONE PLACE DEC. = ±.020	DETAILED		
	TWO PLACE DEC. = ±.010	CHECKED		
	THREE PLACE DEC. = ±.005	SUP'V.		
		ENG. Q.C.		

Honeywell

NAME FLUIDICS TEST STATION
PART — INSTR.
OP. — MACH. — E.O.
NO. SHEETS 6 — SHEET NO. 6 — SIZE A — YG 1158-E100

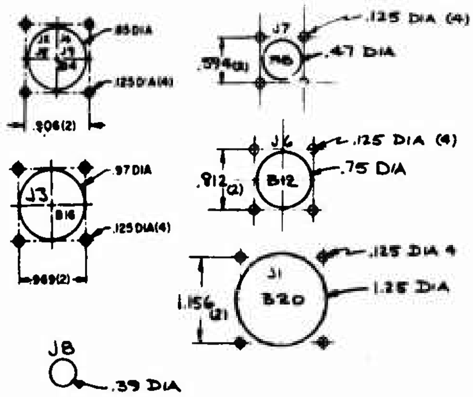
81-3261-001

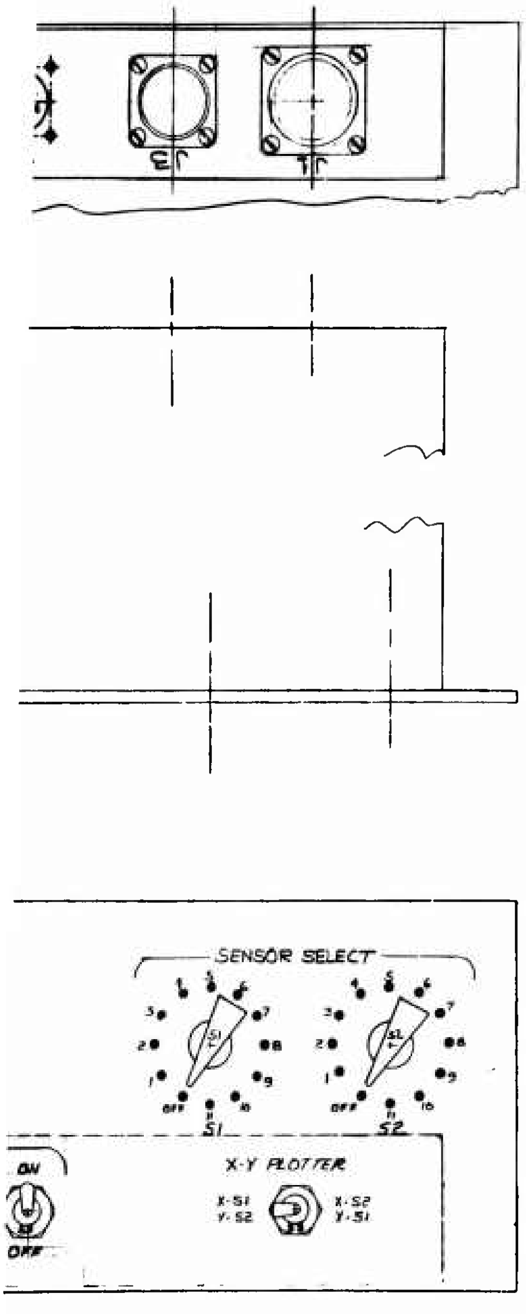
STRIVE TOWARD ERROR-FREE PERFORMANCE


J6
J8
J7
J2
J4
J5
J9
J3
P1
CONTROL PANEL
DVM
EXT
INT
PID
FLO METER SELECT
OFF
SERVO VALVES
OFF
SENS
S1
FLUID FLOW BENCH
115 V 60 Hz
10 A
ON
OFF
PID
ON
OFF
R1
X-Y
X-S1
Y-S2
UPDATE PER CUST. REQ.
ORIGINAL DRAWING
HOLM
STRIVE TOWARD ERROR-FREE PERFORMANCE

2

TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT OF GAGE & LAST REV LETTER). DON'T FORGET SAFETY





R1	24	1	POTENTIOMETER	AMPHENOL 4201B	10 TURN	5K
J12	23	1	BANANA JACK	EF JOHNSON #108-0902-001		RED
J11	22	1	BANANA JACK	EF JOHNSON #108-0903-001		BLK
J10	21	1	BANANA JACK	EF JOHNSON #108-0901-001		WHT
XS1,2,4,6,9	20	5	KNOB	WALDOM #WA2300	67-166	OR 67-163
S7	19	1	SWITCH	ROWAN FCA-W-R		
	18					
S5,8	17	2		MICRO BA2011		
S4,6,9	16	3		OAK 399-477-JC		
S3	15	1		MICRO BA4011		
S1,2	14	2	SWITCH	OAK 399-471-JC		
XP1	13	1	STRAIN RELIEF	HEYCO SR-6P3-4		
P1	12	1	POWER CORD	BELDEN #17408-B		
J9	11	1	CONNECTOR	PT02A-14-5P		
J8	10	1		AMPH #31-102		BNC
J6	9	1		PT02A-12-10S		
J5	8	1		PT02A-14-5S		
J7	7	1		PT02A-8-4P		
J3	6	1		PT02A-16-8S		
J2,4	5	2		PT02A-14-15S		
J1	4	1	CONNECTOR	PT02A-20-39S		
F1	3	1	FUSE	10AMP 1/4" X 1 1/4		
	2	1	CHASSIS	BUD # AC-1416		2x7x17
	1	1	PANEL	BUD # PA-1103		5 1/4"
	DET	REQ	NAME	FINISHED SIZE / MAT'L / HEAT TR	MAT'L USED	WT OR FT / UNIT PRICE / TOTAL

TOLERANCES UNLESS NOTED	DESIGNED FOR	**Honeywell**
MACH ± 1° FORMED ± 2°	PIECES · DATE 1974	NAME TEST CONTROL PANEL
ONE PLACE DEC ± .030	DRAWN RAY A 19 JUN	PART · INSTR
TWO PLACE DEC ± .010	DETAILED	OP · MACH · EO
THREE PLACE DEC ± .005	CHECKED	NO SHEETS 3 · SHEET NO 1 · SIZE D · YG 1158-E101
REF DWGS	SUP V · ENG QC	

CHG NO. ______ TOOLM ______ BIN ______ CHG TO ______

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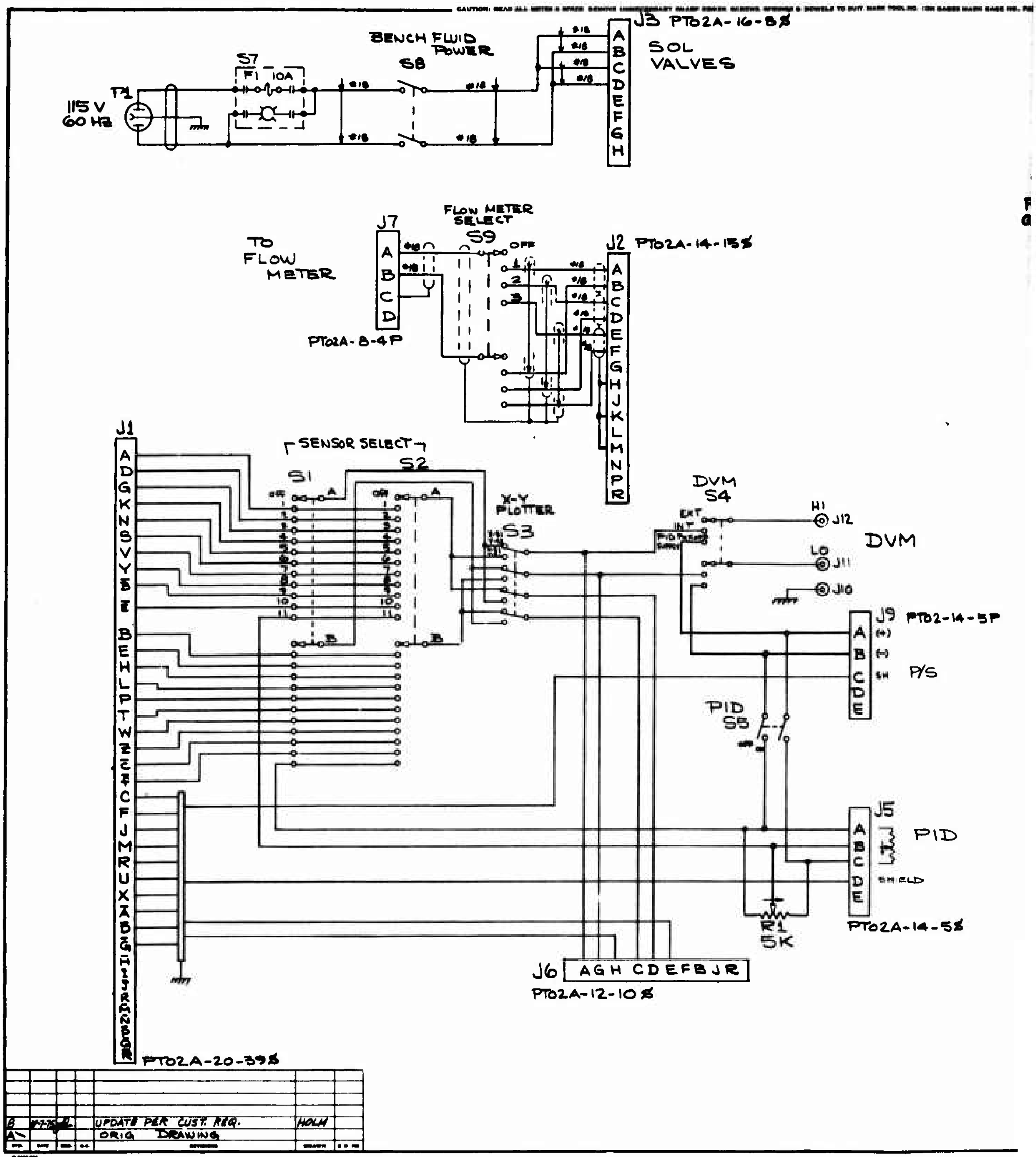
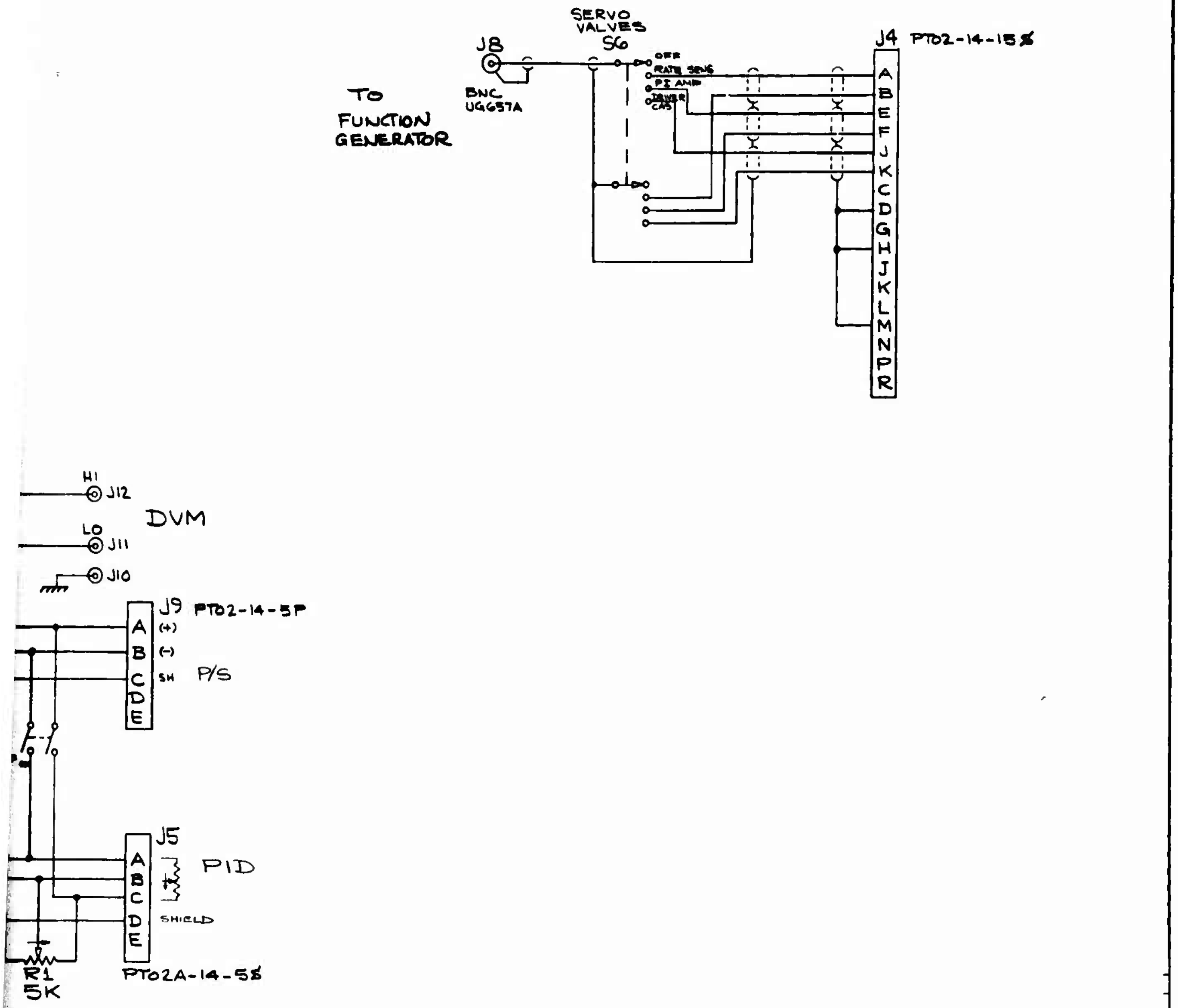


STRIVE TOWARD ERROR-FREE PERFORMANCE

2

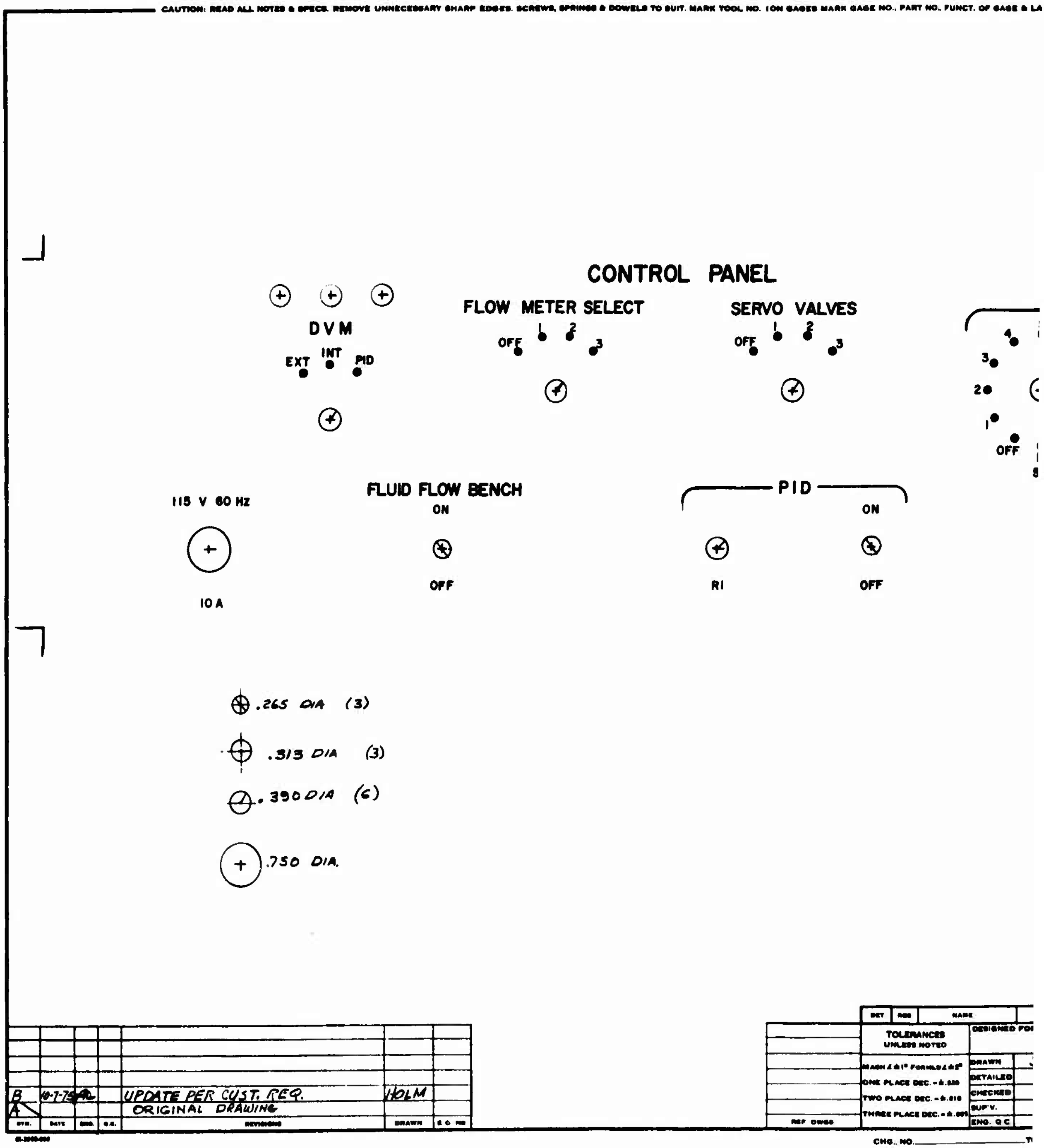
…NGS & DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT OF GAGE & LAST REV LETTER) DON'T FORGET SAFETY



TOLERANCES UNLESS NOTED	DESIGNED FOR / PIECES	DATE 1974	Honeywell
MACH ± 1° FORMING ± 2°	DRAWN RAY A	19 JUN	NAME TEST CONTROL PANEL
ONE PLACE DEC ± .030	DETAILED		PART / INSTR
TWO PLACE DEC ± .010	CHECKED		OP / MACH / E O
THREE PLACE DEC ± .005	SUP V / ENG Q C		NO SHEETS 3 / SHEET NO 2 / SIZE D / YG1158-E101

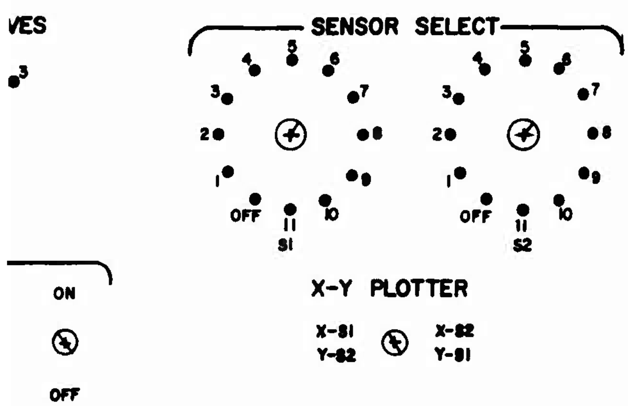
REF DWGS

CHG NO ______ TOOL# ______ BIN ______ CHG TO ______


CAUTION: READ ALL NOTES & SPECS. REMOVE UNNECESSARY SHARP EDGES. SCREWS, SPRINGS & DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LA
CONTROL PANEL
DVM
EXT
INT
PID
FLOW METER SELECT
OFF
1
2
3
SERVO VALVES
OFF
1
2
3
4
3
2
1
OFF
115 V 60 Hz
10 A
FLUID FLOW BENCH
ON
OFF
PID
RI
ON
OFF
.265 DIA (3)
.313 DIA (3)
.390 DIA (6)
.750 DIA.
B 10-7-75
UPDATE PER CUST. REQ.
HOLM
A
ORIGINAL DRAWING
SYM.
DATE
REVISIONS
DRAWN
REF DWGS
TOLERANCES UNLESS NOTED
ONE PLACE DEC.
TWO PLACE DEC.
THREE PLACE DEC.
DESIGNED FOR
DRAWN
DETAILED
CHECKED
SUP'V.
ENG. Q C
CHG. NO.

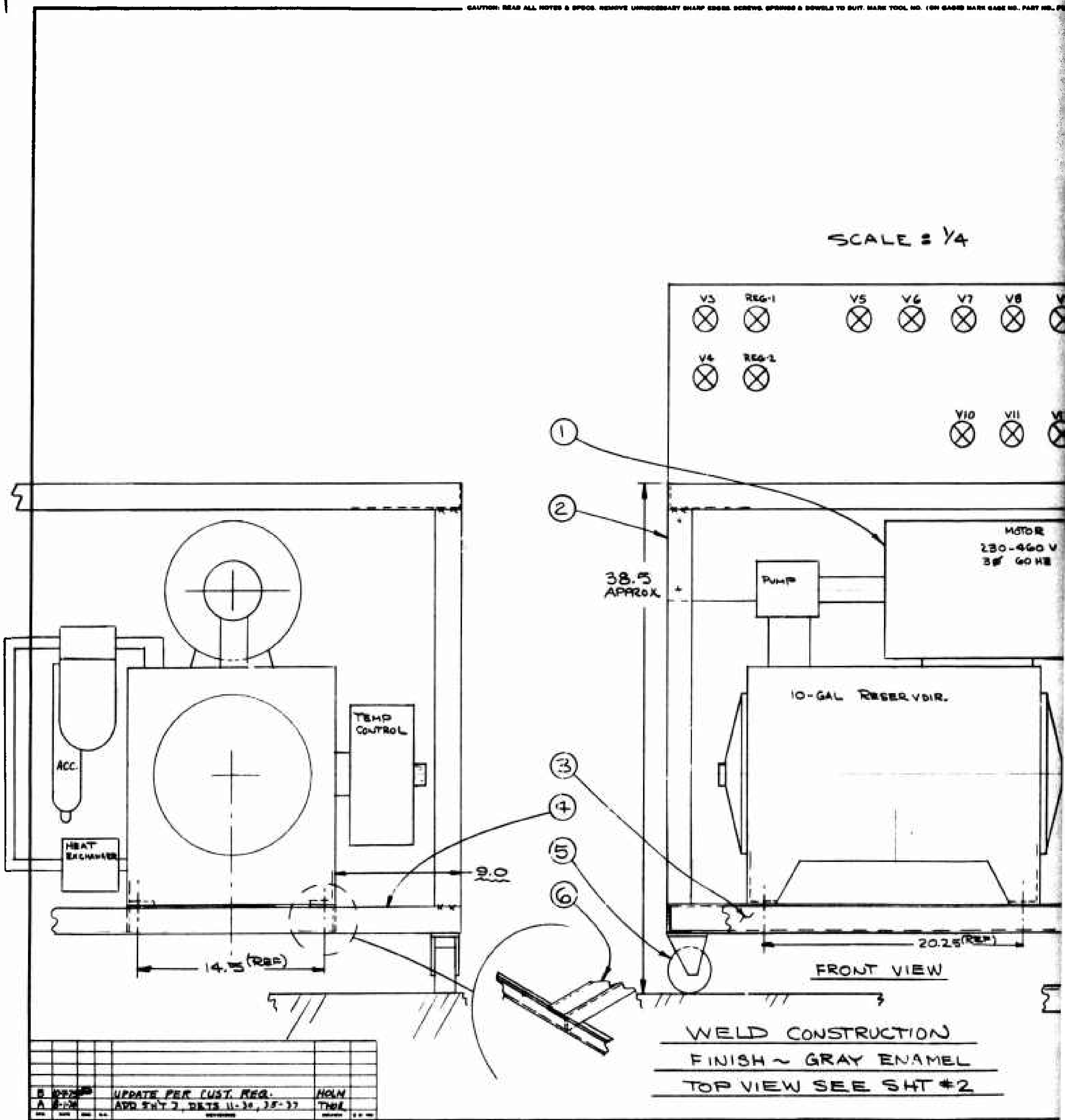
2

ARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY



TOLERANCES UNLESS NOTED	DESIGNED FOR		Honeywell
	PIECES	DATE 1979	NAME TEST CONTROL PANEL
	DRAWN JHA	6-19	PART / INSTR.
ONE PLACE DEC.	DETAILED		OP. / MACH. / E.O.
TWO PLACE DEC.	CHECKED		NO. SHEETS 3 / SHEET NO. 3 / SIZE C / YG 1158-E101
THREE PLACE DEC.	SUP'V.		
	ENG. Q.C.		

CHG. NO. TOOLM. BIN. CHG. TO



STRIVE TOWARD ERROR-FREE PERFORMANCE

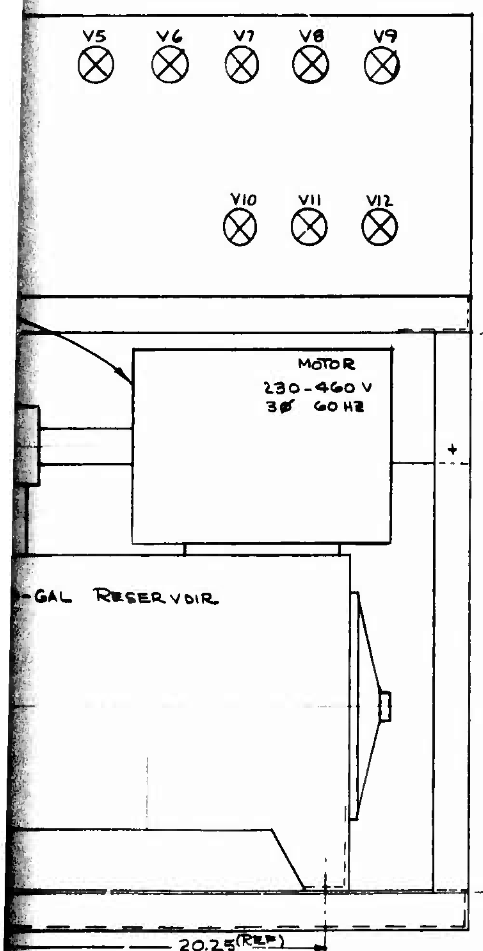
2

...TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY.

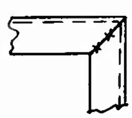
△1 USE ON MIL-H-5606 HYDRAULIC FLUID @ 120°F ALSO WITH MATING CONNECTORS TO 1/4" O.D. TUBE

△2 RATING 6000 PSIG, STAINLESS STEEL BODY, T-BAR ADJ. HANDLE, 1/4" AN PORTS

SCALE = 1/4



FRONT VIEW



...ONSTRUCTION

GRAY ENAMEL

SEE SHT #2

	37	1	FIXTURE	HON. YG 1158-E105		
	36	1	MANIFOLD	HON. YG 1158-E103		
	35	1	PRES. PUMP & GAUGE	HON. 961-005-N		
	34					
	33					
	32					
	31					
ACC-1	30	1	ACCUMULATOR	VICKERS A1-10-11		
V3	29	1	VALVE	WHITEY 1RS4		
FC-1	28	1	FLOW CONTROL	PNEU-TROL EFL30S		
	27	1	HOSE ASS'Y	SYNFLEX 3003-03-144-A04-120		
REG-2	26	1	REGULATOR	TESCOM △2 26-2322-34-064 0-250PSI		
REG-1	25	1	REGULATOR	REXROTH DR10-4-10/100Y/5, SUBPLATE G24/5		
FM-1, FM-2	24	2	FLOW METER	FLOW TECHNOLOGY INC. FT-8M1-LB, .07 TO 1.1GPM △1		
TG-1	23	1	TEMP. GAUGE	MARSHALLTOWN #99, 20-240°F, 2 1/2" DIAL, 2 1/2" STEM, HYD.		
PG-2,3	22	2	PRES. GAUGE	MARSHALLTOWN #23, 100 PSI., 2 1/2" DIAL, HYD.		
WS-1	21	1	WATER STRAINER	OCST-1-08-10		
PG1	20	1	PRES. GAUGE	MARSHALLTOWN #23, 160 PSI., 2 1/2" DIAL, HYD.		
V4-12	19	9	VALVE	WHITEY 1VS4		
XFIL-1	18	1	ELEMENT	PUROLATOR 7509200		
FIL-1	17	1	FILTER	PUROLATOR 7509600		
V1,V2	16	2	VALVE	VICKERS DG4S4-012A-50		
	15	1	FITTING	SYNFLEX 3A07-04A04		
	14	1	HOSE ASSY	SYNFLEX 3003-04-144	-144-240	
	13	2	O-RING	MS-28775-005		
	12	1	RESTRICTOR	5/16 DIA. x 9/64	ALUM.	
	11	2	BLOCK	3/4 x 1 1/2 x 1 1/2	ALUM.	
	10	1	TRAY	1/16 X 40 X 40	CRS	
	9	5	SPACER	1/4 X 1/2 X 35	ALUM	
	8	1	SCREEN	1/16 X 36 X 36	PERFORATED STAINLESS STEEL	.12 DIA HOLES 25% OPEN (APPROX)
	7	1	REAR PANEL	1/4 X 24 X 36	ALUM	
	6	2	RAIL	3/16 X 2 X 2 X 36	CRS ANGLE	
	5	4	CASTER	BASSICK H3999	CAP-290#	OR EQUIV
	4	2	SIDE	3/16 X 2 X 2 X 36	CRS ANGLE	
	3	2	FRONT	3/16 X 2 X 2 X 36	CRS ANGLE	
	2	4	LEG	1/8 X 2 X 2 X 30	CRS ANGLE	
	1	1	HYDRAULIC POWER PACKAGE	HON # 66680201	PUR	
	QTY	NO	NAME	FINISHED SIZE	MAT'L USED	WT / UNIT PRICE / TOTAL

TOLERANCES UNLESS NOTED	MACH ±1/2° FORMED ±1° ; ONE PLACE DEC ±.030 ; TWO PLACE DEC ±.010 ; THREE PLACE DEC. ±.005
DESIGNED FOR / PIECES	DATE 1974
DRAWN	RAY A — 12 JUN
DETAILED	
CHECKED	
SUP'V	6-19-74
ENG	7-1-74
REF DWGS	

Honeywell

NAME HYDRAULIC TEST BENCH

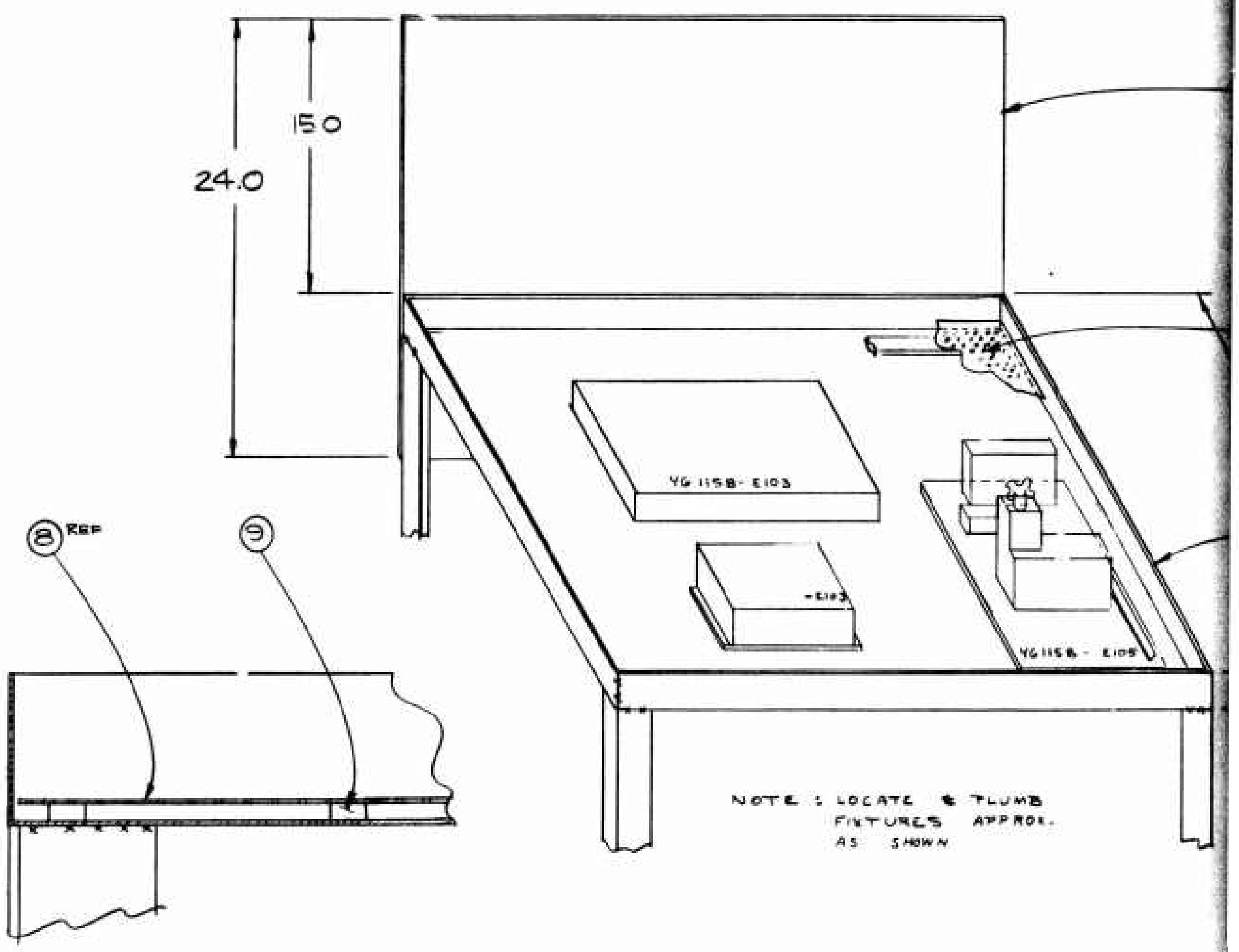
PART — MOTR — OP. — MACH. — E.O.

NO. SHEETS 3 — SHEET NO 1 — SIZE D — YG1158-E102

CHG NO ______ TOOL# ______ BIN ______ CHG TO ______

PRECEDING PAGE BLANK-NOT FILMED

CAUTION: READ ALL NOTES & SPECS REMOVE UNNECESSARY SHARP EDGES SCREWS, SPRINGS & DOWELS TO SUIT MARK TOOL NO. (ON GAGES MARK GAGE NO.

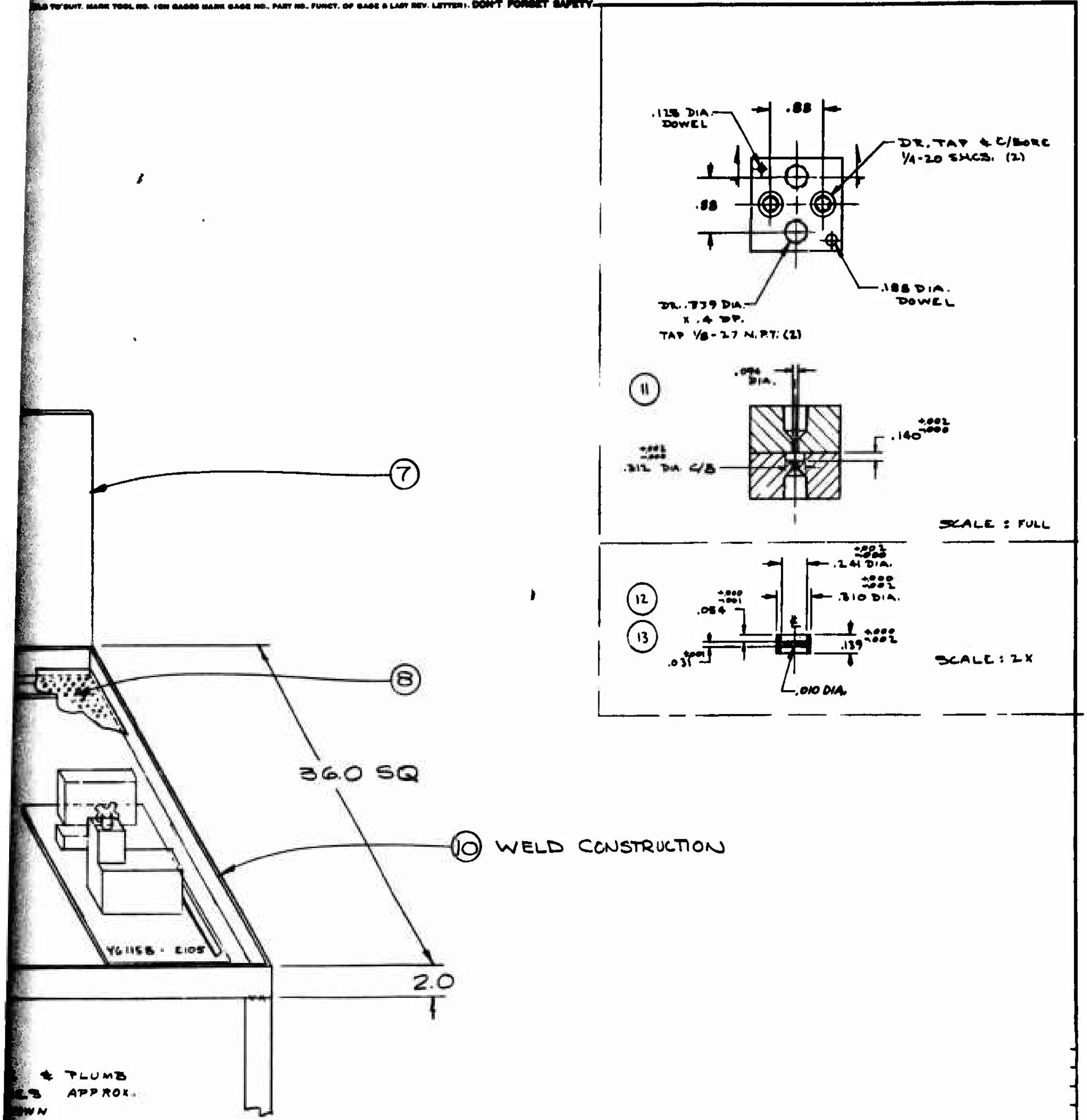


LTR	DATE	ENG.		REVISIONS	DRAWN	
B	10-7-75			UPDATE PER CUST. REQ.	HOLM	
A	9-1-74	SPD		ADD DET'S 11-13	THR	

Strive Toward Error-Free Performance

2

...TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY.



Honeywell

NAME HYDRAULIC TEST BENCH

DATE 1974

DRAWN RAY A 14 JUN

NO. SHEETS 3 SHEET NO. 2 SIZE D YG1158-E102

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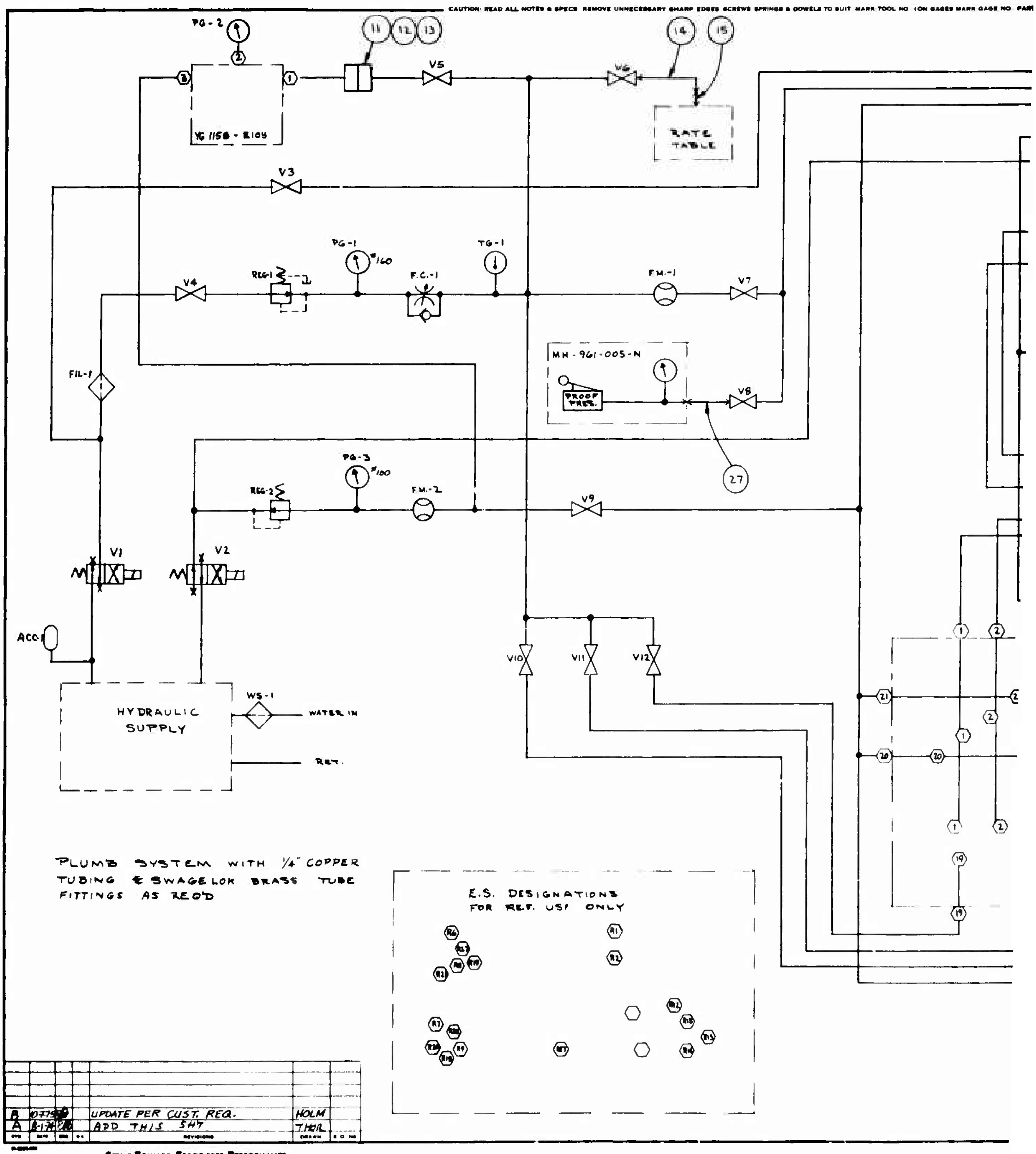
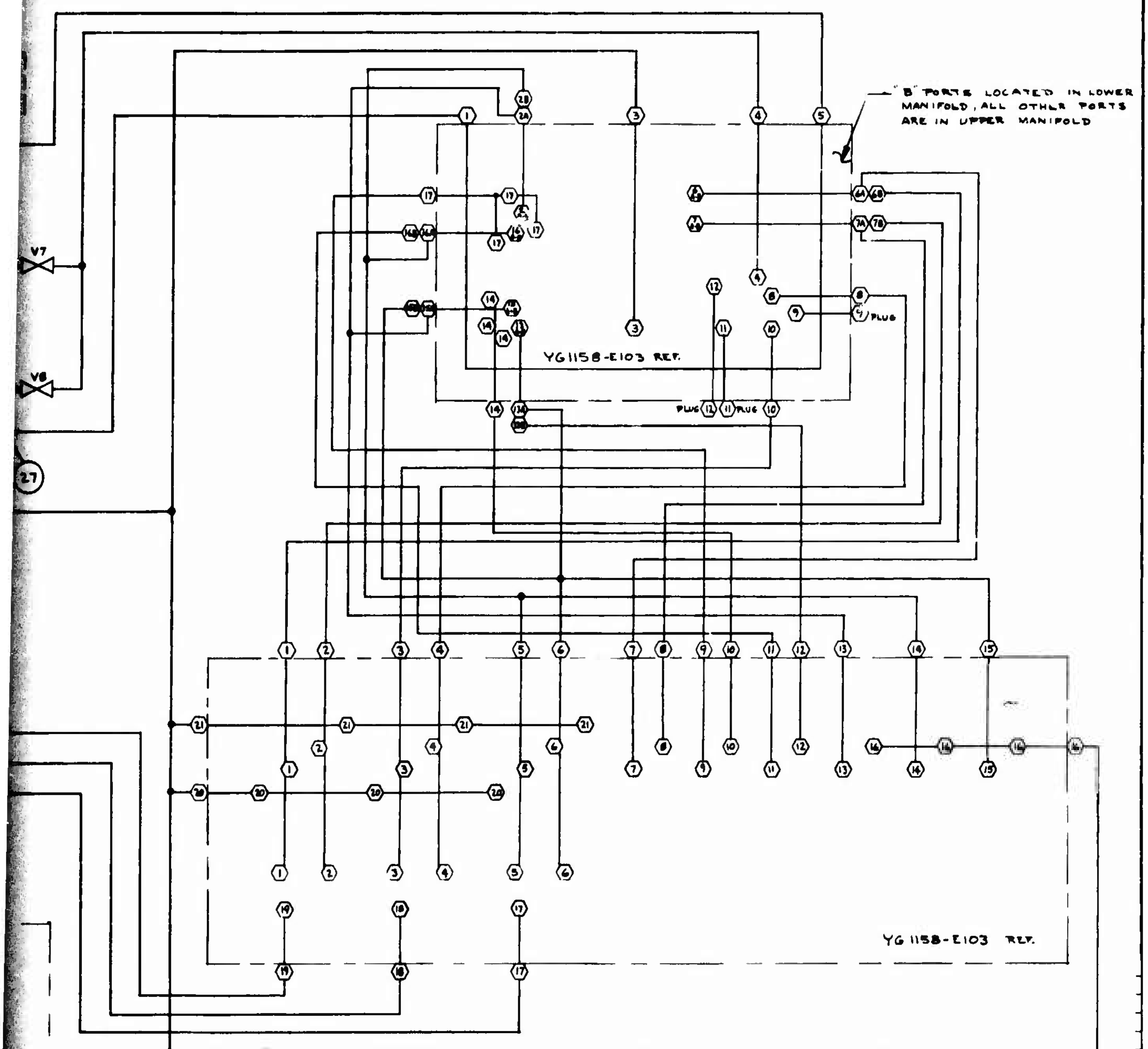


2

...SPRINGS & DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO. PART NO., FUNCT OF GAGE & LAST REV LETTER). DON'T FORGET SAFETY



TOLERANCES UNLESS NOTED	DESIGNED FOR	**Honeywell**
	DRAWN THOR 8-1-74	NAME HYDRAULIC TEST BENCH
	DETAILED	PART
	CHECKED	OP. MACH
	SUP V	NO SHEETS 3
REF DWGS	ENG O.C.	SHEET NO 3
		SIZE D
		YG1158-E102

CHG NO. ____ TOOL# ____ BIN ____ CHG TO ____

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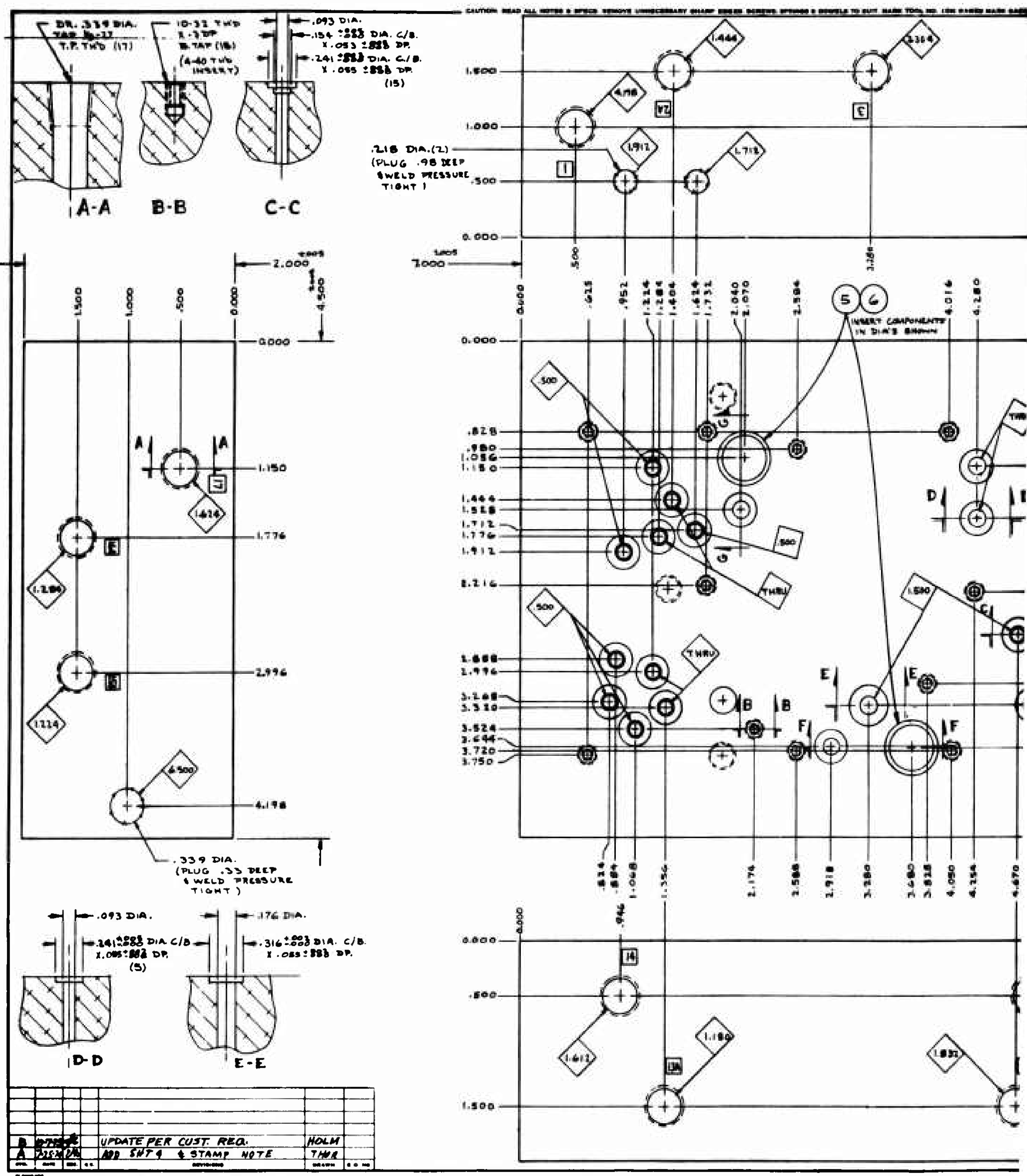
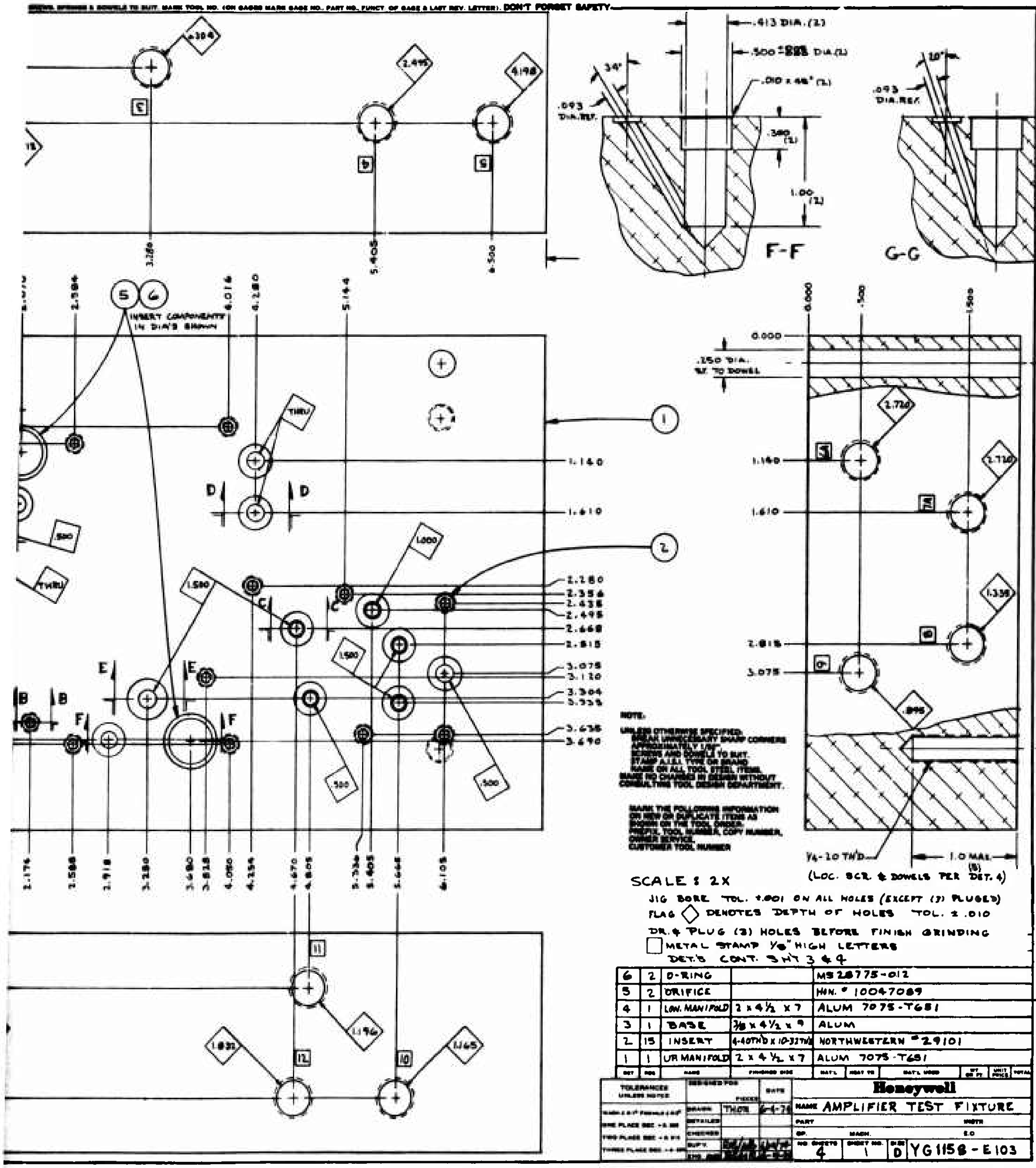


Strive Toward Error-free Performance

2

SCREWS, SPRINGS & DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY.



NOTE:
UNLESS OTHERWISE SPECIFIED:
BREAK UNNECESSARY SHARP CORNERS APPROXIMATELY 1/64".
SCREWS AND DOWELS TO SUIT.
STAMP A.I.S.I. TYPE OR BRAND NAME ON ALL TOOL STEEL ITEMS.
MAKE NO CHANGES IN DESIGN WITHOUT CONSULTING TOOL DESIGN DEPARTMENT.

MARK THE FOLLOWING INFORMATION ON NEW OR DUPLICATE ITEMS AS SHOWN ON THE TOOL ORDER.
PREFIX, TOOL NUMBER, COPY NUMBER,
OWNER SERVICE,
CUSTOMER TOOL NUMBER

(LOC. SCR. & DOWELS PER DET. 4)

SCALE : 2X

JIG BORE TOL. ±.001 ON ALL HOLES (EXCEPT (3) PLUGED)
FLAG ◇ DENOTES DEPTH OF HOLES TOL. ±.010
DR. & PLUG (3) HOLES BEFORE FINISH GRINDING
☐ METAL STAMP 1/8" HIGH LETTERS
DET'S CONT. SH'T 3 & 4

DET	REQ	NAME	FINISHED SIZE	MAT'L	HEAT TO	MAT'L USED	WT OR FT	UNIT PRICE	TOTAL
6	2	O-RING		MS 28775-012					
5	2	ORIFICE		H.W. # 10047089					
4	1	LOW. MANIFOLD	2 x 4 1/2 x 7	ALUM 7075-T651					
3	1	BASE	3/8 x 4 1/2 x 9	ALUM					
2	15	INSERT	4-40THD x 10-32THD	NORTHWESTERN #29101					
1	1	UP. MANIFOLD	2 x 4 1/2 x 7	ALUM 7075-T651					

Honeywell

TOLERANCES UNLESS NOTED

DRAWN: THOM 6-4-74

NAME: AMPLIFIER TEST FIXTURE

NO. SHEETS: 4 | SHEET NO.: 1 | SIZE: D | YG 1158 - E103

CHG NO. ______ TOOL# ______ DIV ______ CHG TO ______

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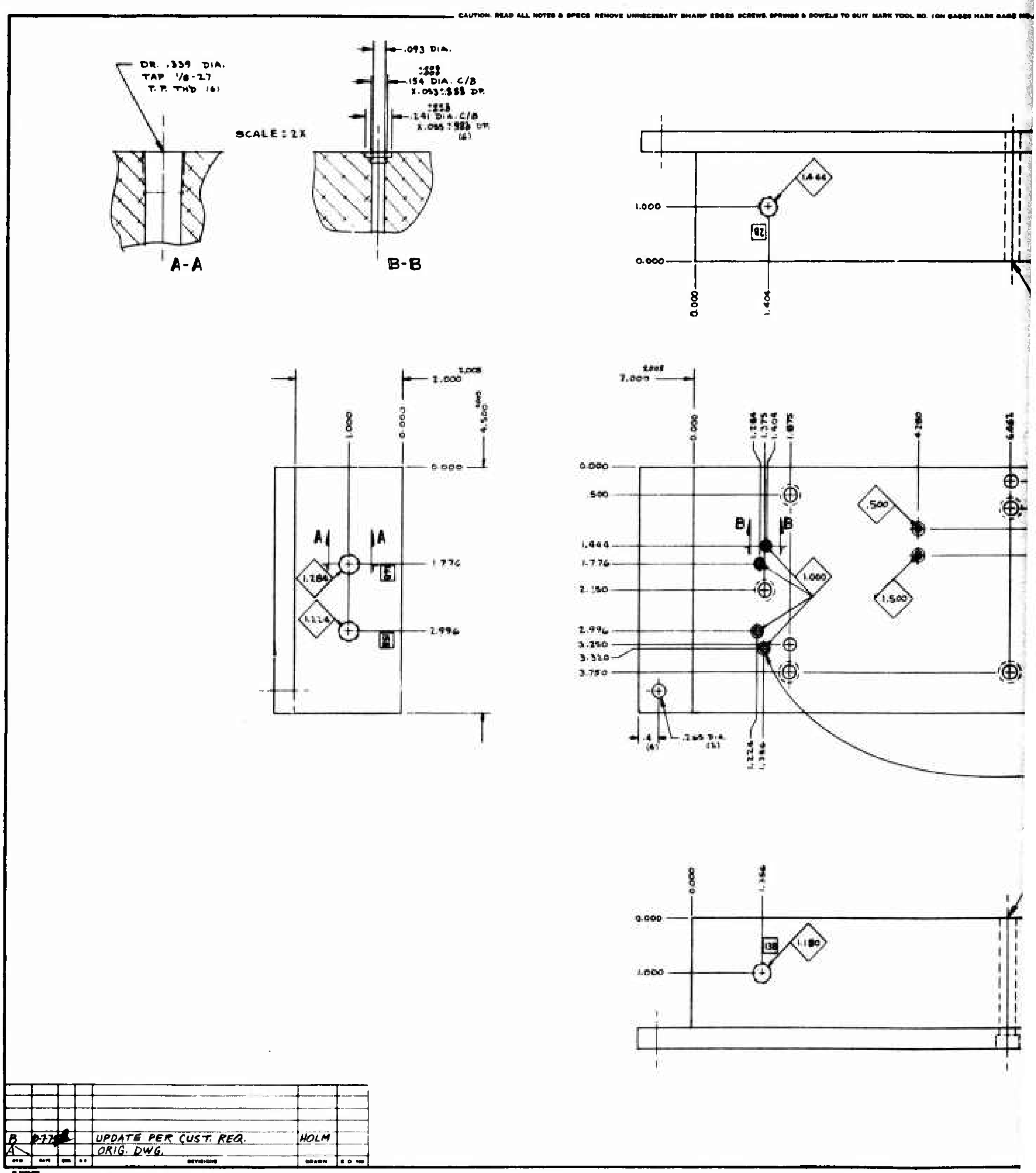
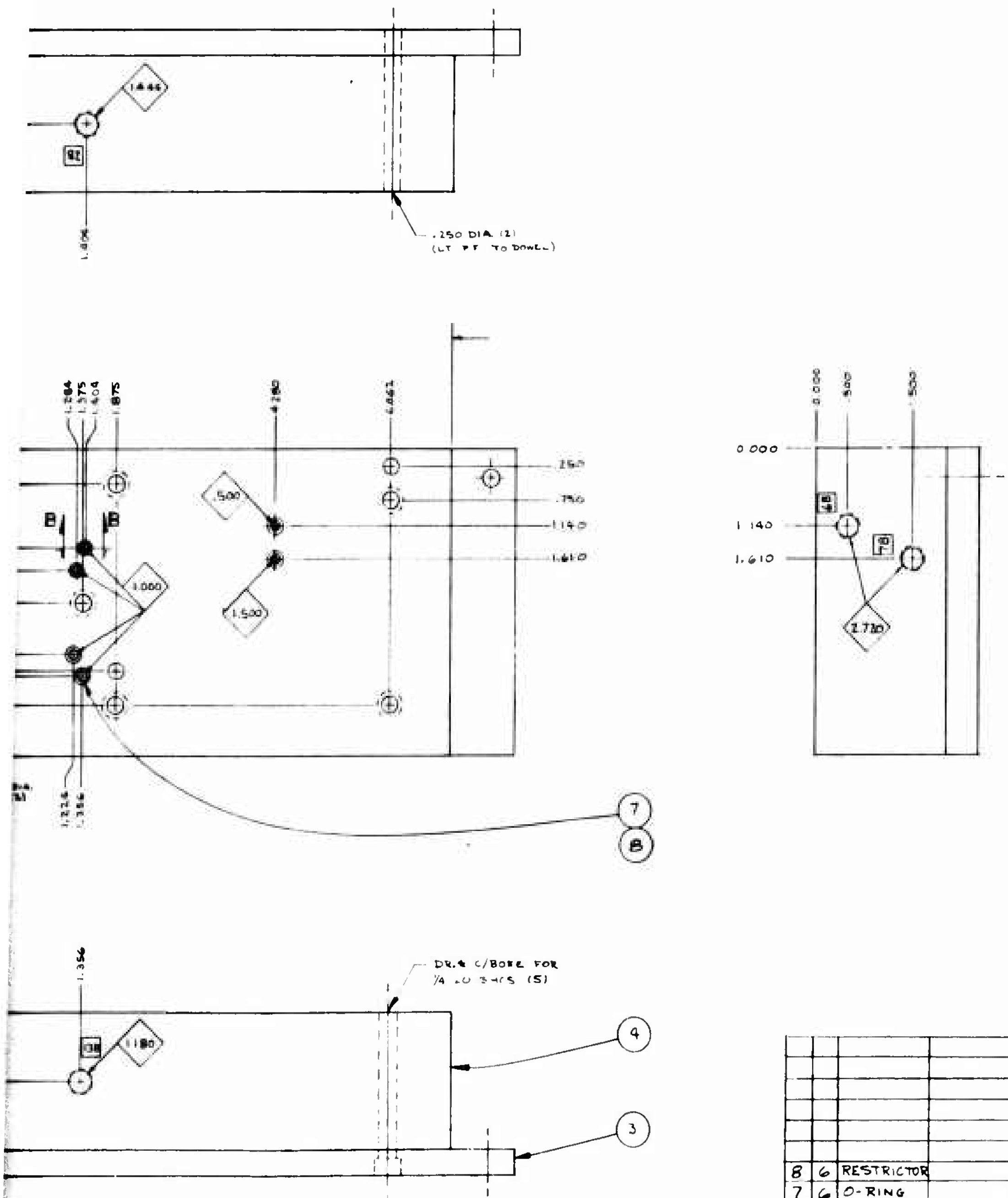


Strive Toward Error-Free Performance

...SCREWS, SPRINGS & DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO. PART NO., FUNCT. OF GAGE & LAST REV. LETTER) DON'T FORGET SAFETY



8	6	RESTRICTOR		TO BE DETERMINED AT CALIB.					
7	6	O-RING		MS 28775-005					
QTY	REQ	NAME	FINISHED SIZE	MAT'L	HEAT TR	MAT'L USED	WT OR FT	UNIT PRICE	TOTAL

TOLERANCES UNLESS NOTED	DESIGNED FOR	DATE	**Honeywell**
MACH ± 1° FORM ± 2°	DRAWN THOR	6-4-74	NAME AMPLIFER TEST FIXTURE
ONE PLACE DEC ± .020	DETAILED		PART / INSTR
TWO PLACE DEC ± .010	CHECKED		OP / MACH / ED
THREE PLACE DEC ± .005	SUP V / ENG QC		NO SHEETS 4 / SHEET NO 2 / SIZE D / YG1158-E103

REF DWGS

CHG NO TOOLM BIN CHG TO

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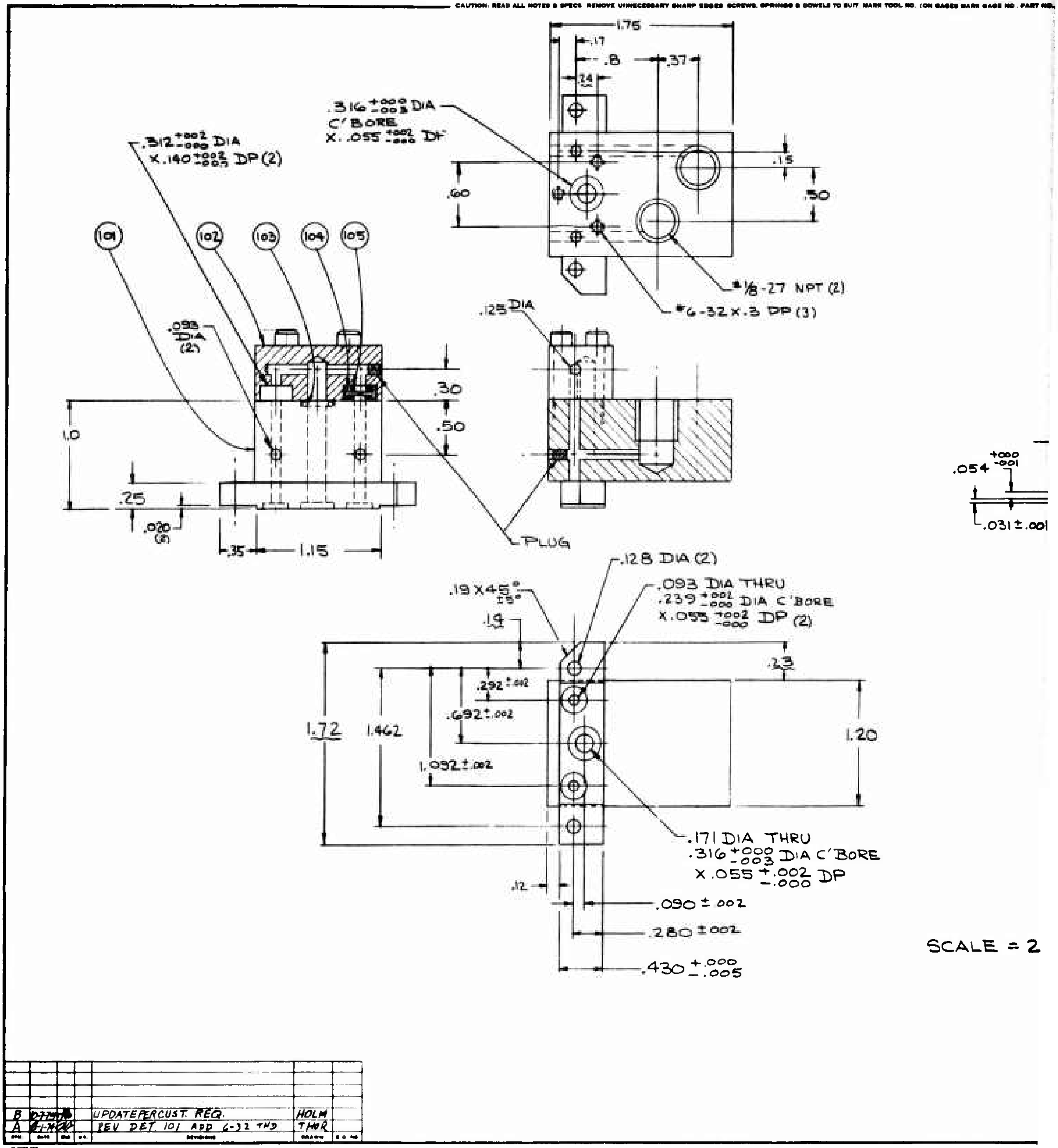
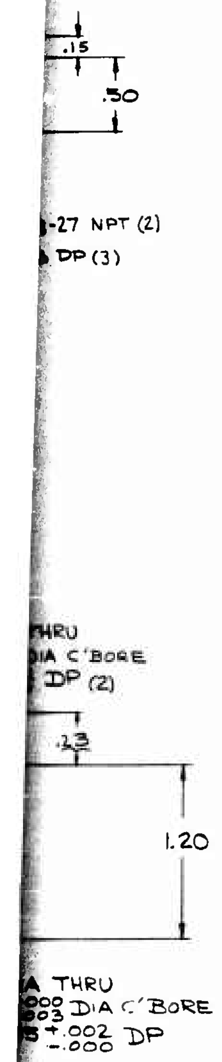
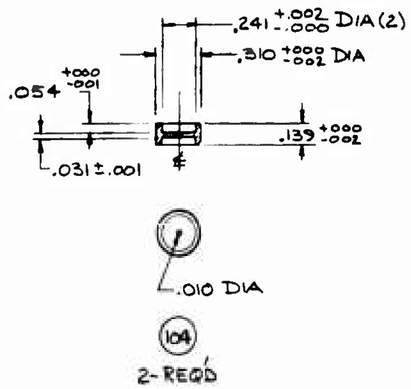


STRIVE TOWARD ERROR-FREE PERFORMANCE

DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO. PART NO. FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY.





SCALE = 2X

OUTLET BLOCK

105	4	O' RING	MS 28775-005	PUR				
104	2	RESTRICTOR	3/16 DIA x 3/32	ALUM	2024-T3			
103	1	O' RING	MS 28775-008	PUR				
102	1	CAP	1/2 x 7/8 x 1 1/4	ALUM	2024-T4			
101	1	HOUSING	1 x 1 3/4 x 1 7/8	ALUM	2024-T3			

TOLERANCES UNLESS NOTED

100500 34

100500 24

Honeywell

NAME AMPLIFIER TEST FIXTURE

DRAWN RAY A. 5 JUN

NO. SHEETS 4 SHEET NO. 3 D YG1158-E103

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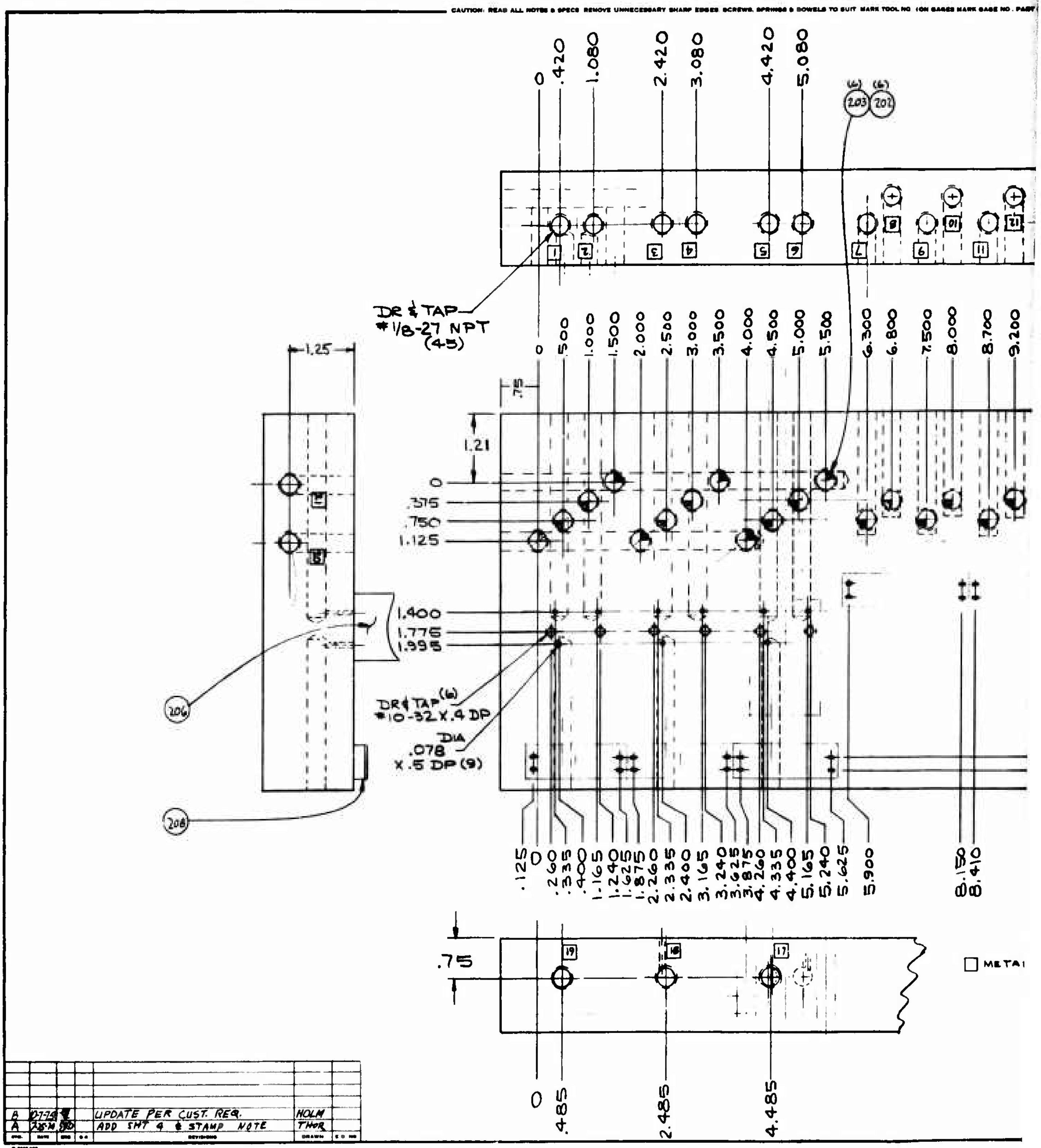
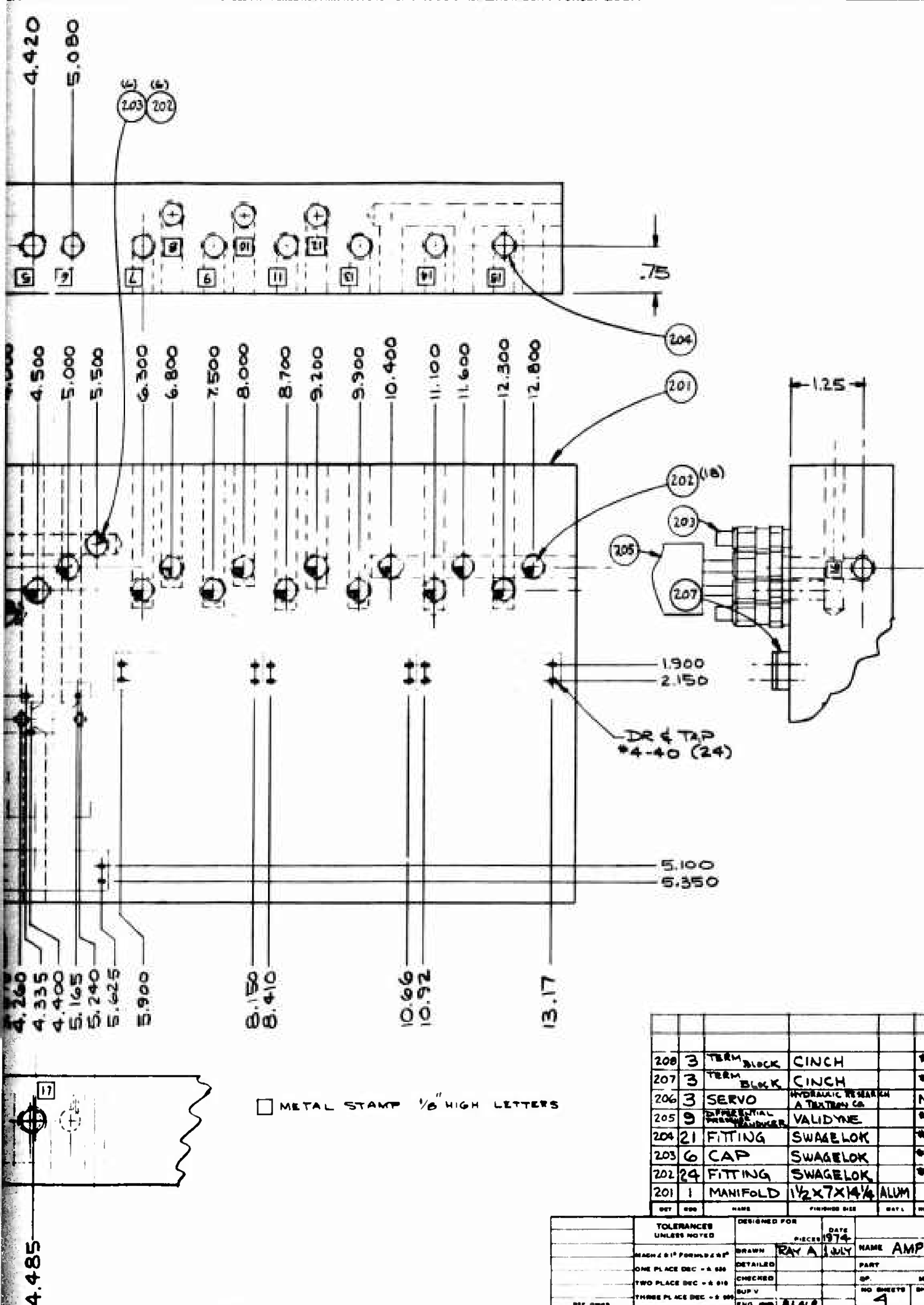


STRIVE TOWARD ERROR-FREE PERFORMANCE

2

SPRINGS & DOWELS TO SUIT MARK TOOL NO (ON GAGES MARK GAGE NO. PART NO. FUNCT OF GAGE & LAST REV LETTER) DON'T FORGET SAFETY

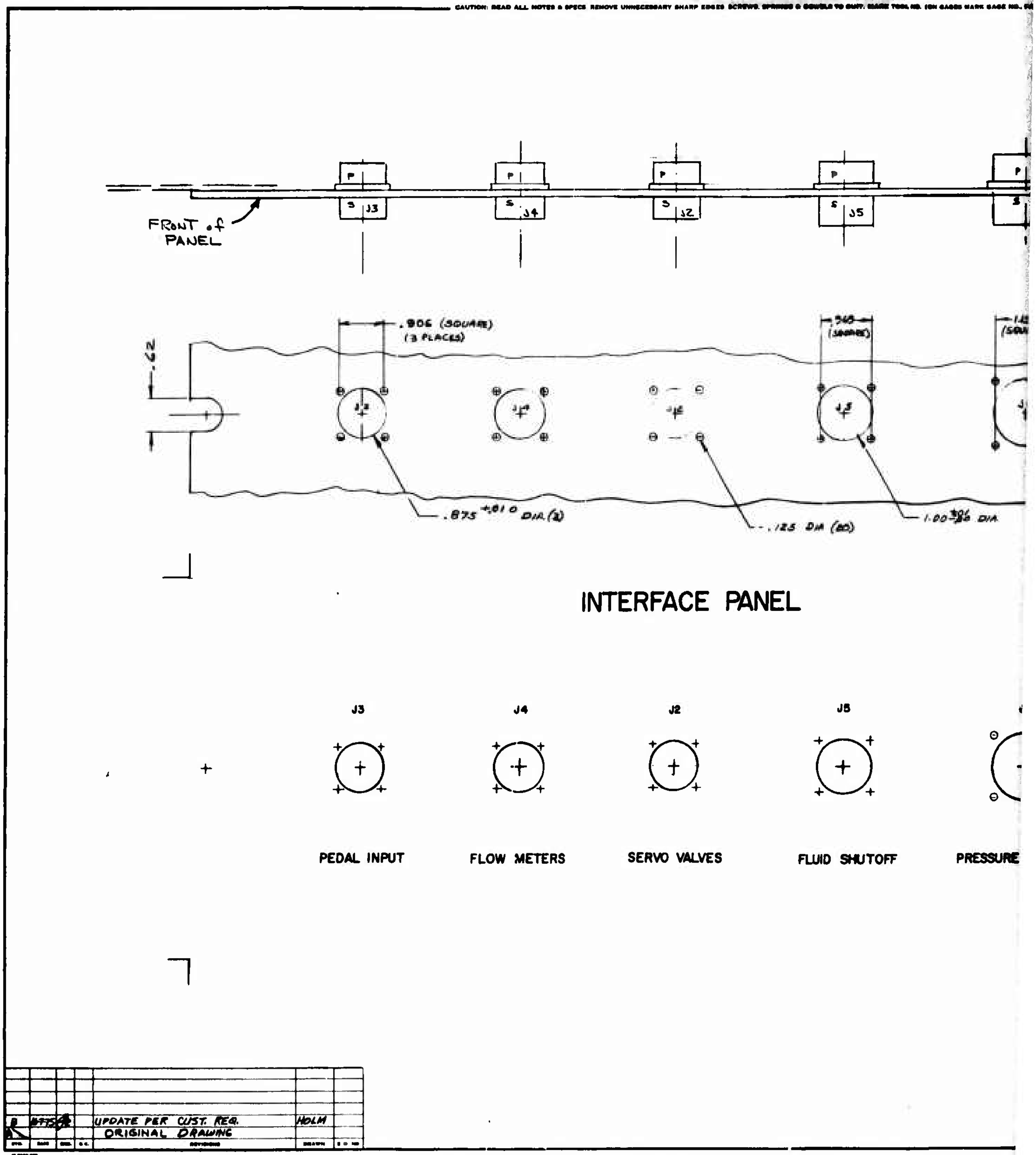


DET	REQ	NAME	FINISHED SIZE	MAT'L	HEAT TR / MAT'L USED		WT OR FT	UNIT PRICE	TOTAL
208	3	TERM BLOCK	CINCH		# 6-172				
207	3	TERM BLOCK	CINCH		# 8-172				
206	3	SERVO	HYDRAULIC RESEARCH A TEXTRON CO.		MODEL #20	1ST STAGE P/N 200560-1	ONLY		
205	9	DIFFERENTIAL PRESSURE TRANSDUCER	VALIDYNE		# DP9				
204	21	FITTING	SWAGELOK		#400-1-2				
203	6	CAP	SWAGELOK		#200-C				
202	24	FITTING	SWAGELOK		#200-1-2				
201	1	MANIFOLD	1½×7×14¼	ALUM					

TOLERANCES UNLESS NOTED MACH ∠ ±1° FORMED ∠ ±2° ONE PLACE DEC ±.030 TWO PLACE DEC ±.010 THREE PLACE DEC ±.005 REF DWGS	DESIGNED FOR PIECES — DATE 1974 DRAWN RAY A — JULY DETAILED CHECKED SUP V ENG	**Honeywell** NAME AMPLIFIER TEST FIXTURE PART — INSTR OP. — MACH — E O NO SHEETS 4 — SHEET NO 4 — SIZE D — YG1158-E103

CHG NO — TOOLM — SIN — CHG TO

PRECEDING PAGE BLANK-NOT FILMED

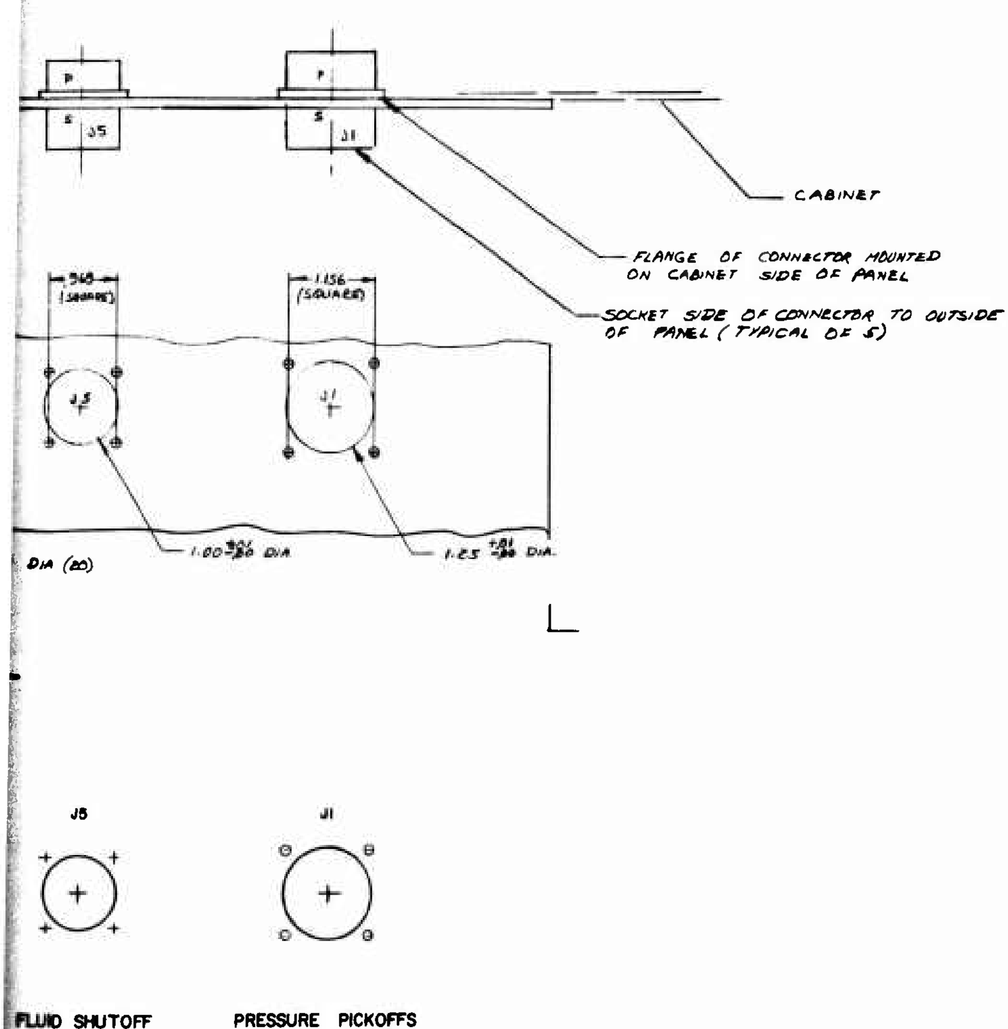


INTERFACE PANEL

STRIVE TOWARD ERROR-FREE PERFORMANCE

2

DOWELS TO SUIT MARK TOOL NO (ON GAGES MARK GAGE NO PART NO. FUNCT OF GAGE & LAST REV LETTER). DON'T FORGET SAFETY



	DET	REQ	NAME	FINISHED SIZE		MAT'L
	5	1	PANEL	BUD #PA1104		PUR.
J3	4	1	CONNECTOR	BENDIX # PTB-14-5PS		PUR
J5	3	1	CONNECTOR	BENDIX # PTB-16 8PS		PUR.
J2, J4	2	2	CONNECTOR	BENDIX # PTB-14-15PS		PUR.
J1	1	1	CONNECTOR	BENDIX # PTB-20-41PS		PUR.

HEAT TR | MAT'L USED | WT OR FT | UNIT PRICE | TOTAL

TOLERANCES UNLESS NOTED	DESIGNED FOR PIECES	DATE 1974	**Honeywell**
MACH ∠ ±1° FORMED ∠ ±2°	DRAWN JWA	9-25	NAME INTERFACE PANEL
ONE PLACE DEC ±.030	DETAILED		PART INSTR
TWO PLACE DEC ±.010	CHECKED		OP MACH EO
THREE PLACE DEC. ±.005	SUP V		NO SHEETS 1 SHEET NO 1 SIZE D YG 1158-E104
REF DWGS	ENG QC		

CHG NO ______ TOOLM ______ BIN ______ CHG TO ______

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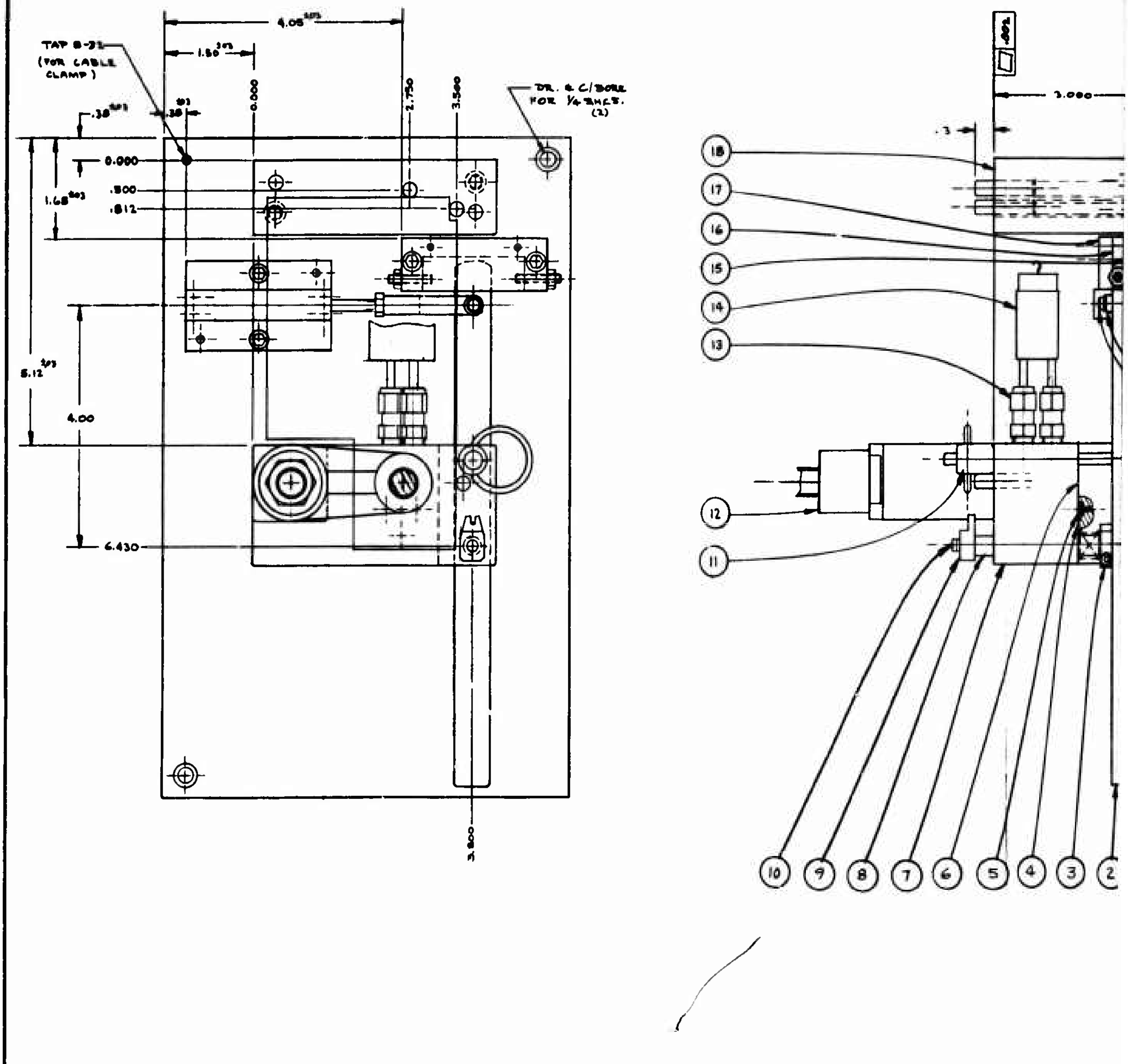
CAUTION: READ ALL NOTES & SPECS REMOVE UNNECESSARY SHARP EDGES SCREWS, SPRINGS & DOWELS TO SUIT MARK TOOL NO. (ON GAGES MARK GAGE NO.

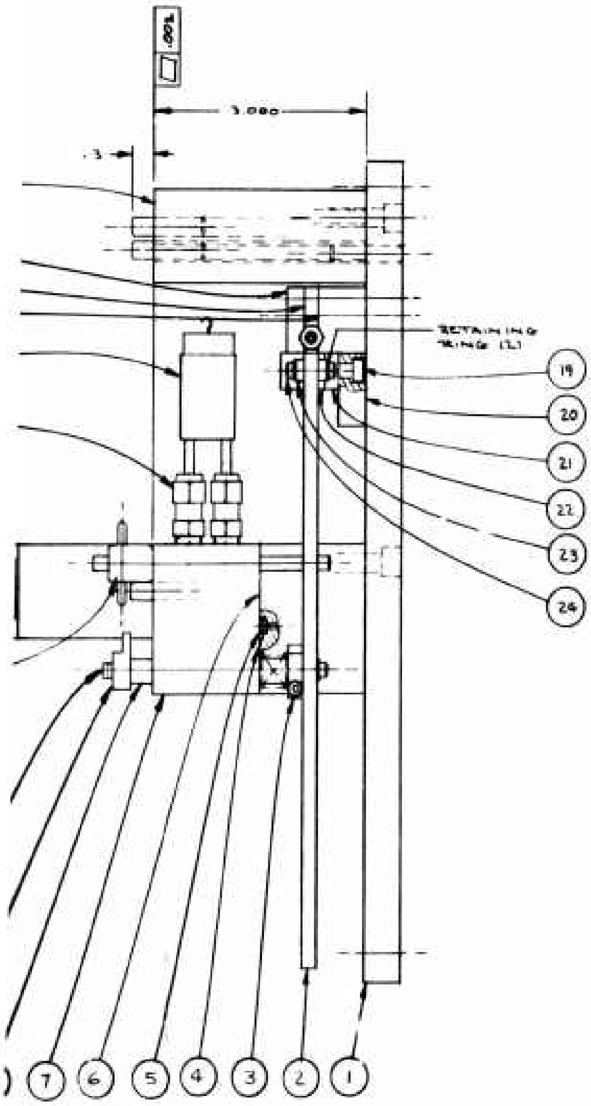


B			UPDATE PER CUST. REQ.	HOLM	
A			ADD STAMP NOTE SHT 2	THOR	
SYM.	DATE	CHG.	REVISIONS	DRAWN	

Strive Toward Error-free Performance

2

OWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV. LETTER). DON'T FORGET SAFETY



NOTE:

UNLESS OTHERWISE SPECIFIED:
BREAK UNNECESSARY SHARP CORNERS APPROXIMATELY 1/32".
SCREWS AND DOWELS TO SUIT.
STAMP A.I.S.I. TYPE OR BRAND NAME ON ALL TOOL STEEL ITEMS.
MAKE NO CHANGES IN DESIGN WITHOUT CONSULTING TOOL DESIGN DEPARTMENT.

MARK THE FOLLOWING INFORMATION ON NEW OR DUPLICATE ITEMS AS SHOWN ON THE TOOL ORDER:
PREFIX, TOOL NUMBER, COPY NUMBER, OWNER SERVICE, CUSTOMER TOOL NUMBER

24	1	PIN	7/32 DIA. x 3/4	BRASS	
23	1	YOKE			HON. # MS 35812-1
22	1	POTENTIOMETER			BOURNS # 80294-200178 1010
21	1	ADAPTOR	3/16 x 1/2 x 2 1/2	ALUM	2024-T3
20	1	BASE	3/8 x 1 1/2 x 2 1/2	ALUM	2024-T3
19	1	SHOU. SCREW			PIC # 4416 OR EQUIV.
18	1	LOC. BLOCK	1 1/4 x 3 x 4 1/4	ALUM	7075-T651
17	1	COVER	1/4 x 7/8 x 2 1/2	ALUM	2024-T3
16	1	RETAINER	1/16 x 7/8 x 2 1/2	ALUM	2024-T3
15	1	BLOCK	21/32 x 7/8 x 2 1/2	ALUM	2024-T3
14	1	TRANSDUCER			VALIDYNE # DP9
13	2	FITTING			SWAGELOK # 200-1-2
12	1	SWING CLAMP			CARR-LANE # CL-4-SWA-1-N
11	1	LOCK-PIN			CARR-LANE # CL-3-BLP-R-2.5-S
10	1	SHAFT	3/16 DIA x 3 1/8	ST. STL	
9	1	ADAPTOR	1/4 x 7/16 x 3/4	ST STL	
8	2	BUSHING	.1875 I.D. x 5/16 O.D. x 1/4		AMERICAN # PT
7	1	UPR. MANIFOLD	2 x 3 7/8 x 4 1/4	ALUM	7075-T651
6	1	LOW. MANIFOLD	1 1/2 x 2 x 3 1/4	ALUM	7075-T651
5	3	RESTRICTOR	5/16 DIA. x 9/64	ALUM	2024-T3
4	6	O-RING			MS 28775-005
3	1	CLAMP			PIC # LI-4
2	1	HANDLE	3/16 x 5/8 x 8 3/4	ST STL	
1	1	BASE	1/2 x 7 x 11	ALUM	2024-T3

Honeywell

DRAWN THORE 6-13-

NAME PILOT INP TRANSDUCER

NO. SHEETS 2 SHEET NO. 1 D YG1158-E105

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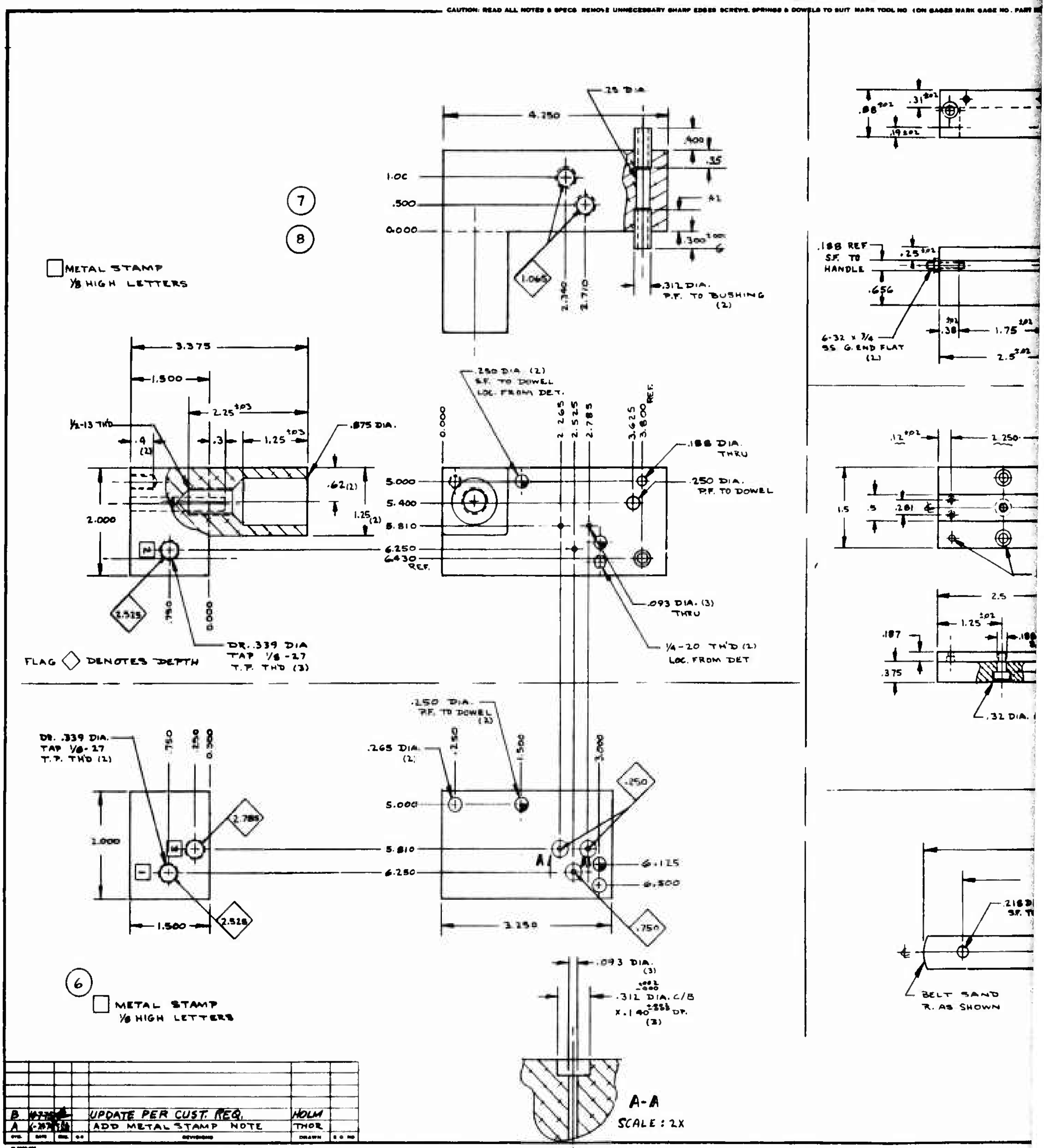
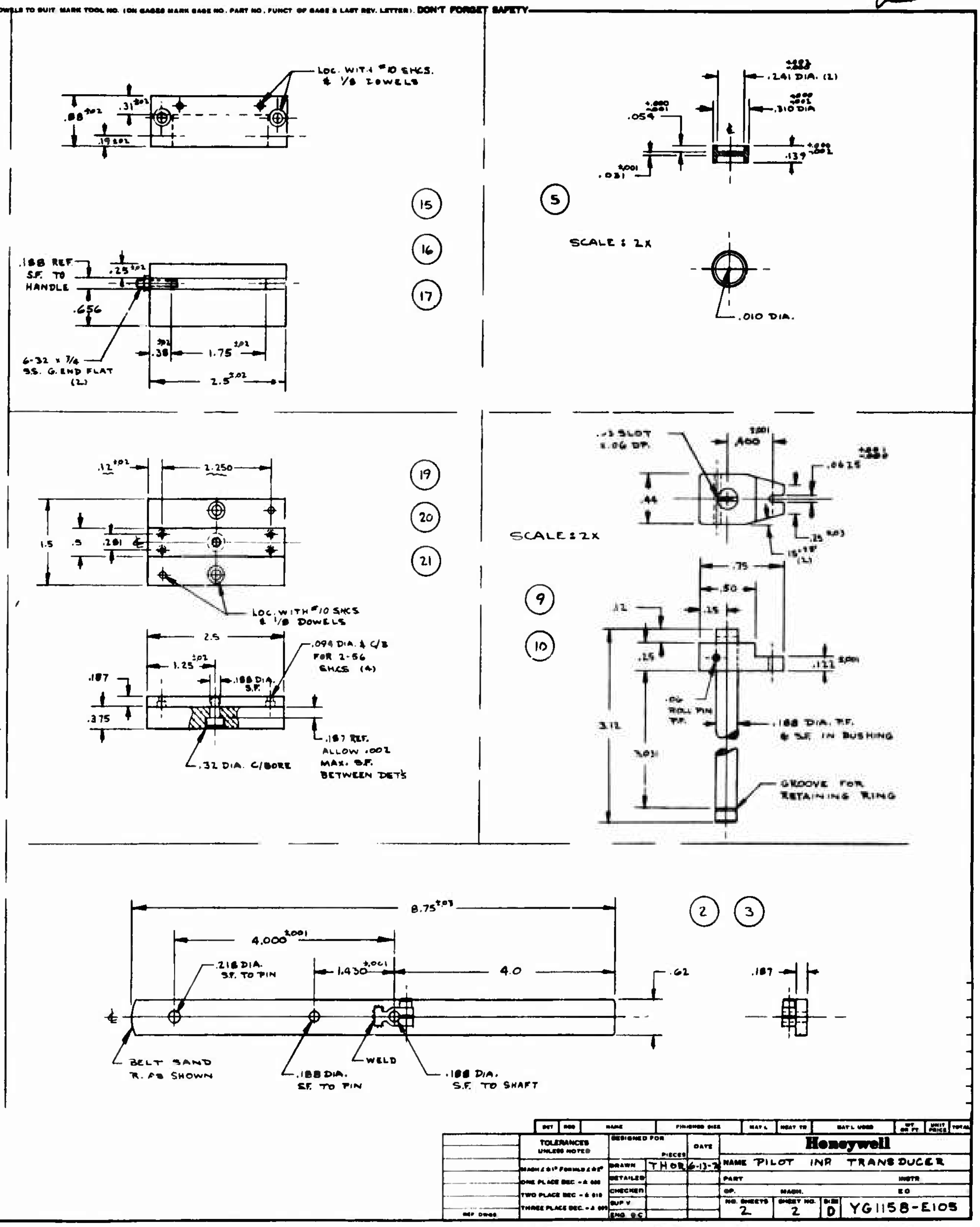


STRIVE TOWARD ERROR-FREE PERFORMANCE

2


DON'T FORGET SAFETY
LOC. WITH #10 SHCS. & 1/8 DOWELS
.188 REF. S.F. TO HANDLE
.656
6-32 x 7/4 S.S. G. END FLAT (2)
1.75
2.5
SCALE : 2X
.241 DIA. (2)
.310 DIA.
.054
.139
.031
.010 DIA.
2.250
1.5
.5
.281
LOC. WITH #10 SHCS & 1/8 DOWELS
.094 DIA. & C/B FOR 2-56 SHCS (4)
1.25
.188 DIA. S.F.
.187
.375
.32 DIA. C/BORE
.187 REF. ALLOW .002 MAX. S.F. BETWEEN DET'S
SCALE : 2X
.400
.0625
.44
.75
.50
.15
.12
.25
3.12
.06 ROLL PIN T.F.
.188 DIA. T.F. & S.F. IN BUSHING
GROOVE FOR RETAINING RING
8.75
4.000
.218 DIA. S.F. TO PIN
1.430
4.0
.62
.187
BELT SAND R. AS SHOWN
.188 DIA. S.F. TO PIN
WELD
.188 DIA. S.F. TO SHAFT
15
16
17
5
19
20
21
9
10
2
3
TOLERANCES UNLESS NOTED
ONE PLACE DEC
TWO PLACE DEC
THREE PLACE DEC
DRAWN
THOR
DETAILED
CHECKER
ENG
Honeywell
NAME PILOT INR TRANSDUCER
PART
NO. SHEETS 2
SHEET NO. 2
D
YG1158-E105

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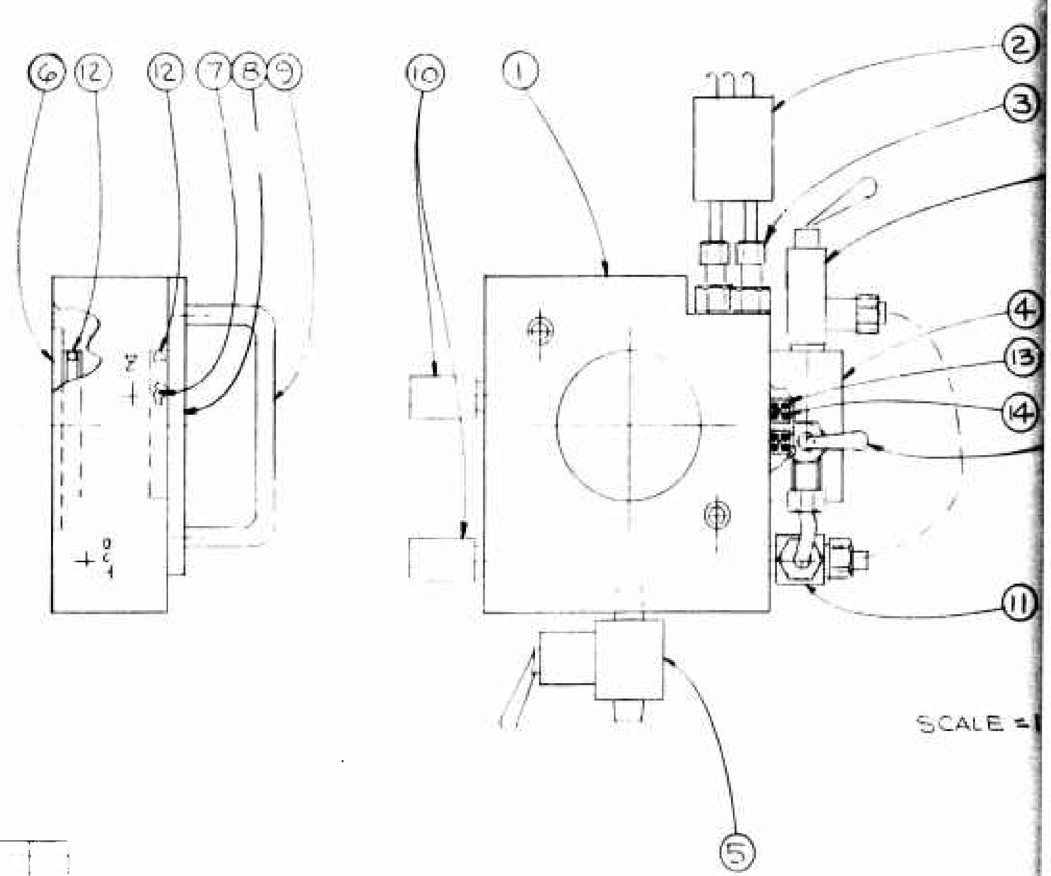
CAUTION READ ALL NOTES & SPECS REMOVE UNNECESSARY SHARP EDGES SCREWS SPRINGS & DOWELS TO SUIT MARK TOOL NO. ION GAGES MARK GAGE NO. PART NO.



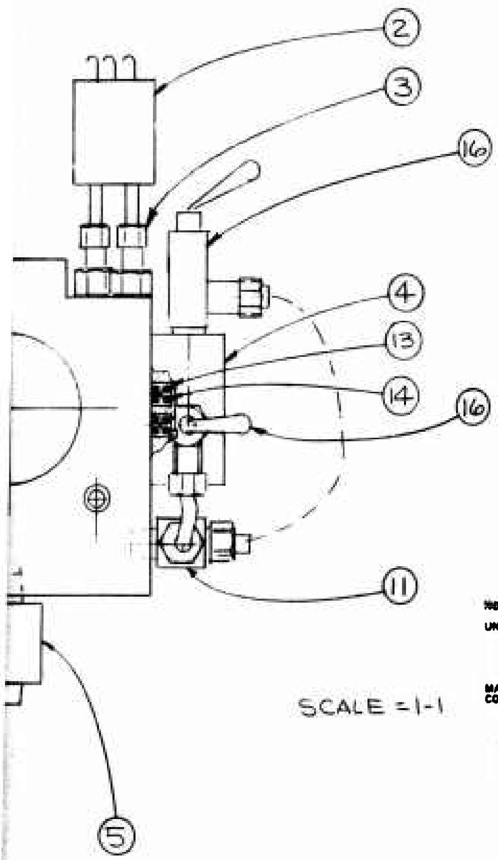
C	UPDATE PER CUST. REQ.		HOLM
B	SEE SHT 3		RAY A
A	(1)WAS 2 REQD, (2) CHG (3) ADD	SHT 1 & 3	RAY A

STRIVE TOWARD ERROR-FREE PERFORMANCE

...S & DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT OF GAGE & LAST REV. LETTER) DON'T FORGET SAFETY

△1 USE ON MIL-H-5606 HYDRAULIC FLUID @ 120°F ALSO WITH MATING CONNECTORS TO 1/4" OD TUBE

△2 RATING 6000 PSIG, STAINLESS STEEL BODY, T-BAR ADJ. HANDLE, 1/4" AN PORTS



SCALE = 1-1

NOTE:

UNLESS OTHERWISE SPECIFIED:
BREAK UNNECESSARY SHARP CORNERS APPROXIMATELY 1/32".
SCREWS AND DOWELS TO SUIT.
STAMP A.I.S.I. TYPE OR BRAND NAME ON ALL TOOL STEEL ITEMS.
MAKE NO CHANGES IN DESIGN WITHOUT CONSULTING TOOL DESIGN DEPARTMENT.

MARK THE FOLLOWING INFORMATION ON NEW OR DUPLICATE ITEMS AS SHOWN ON THE TOOL ORDER:
PREFIX, TOOL NUMBER, COPY NUMBER, OWNER SERVICE, CUSTOMER TOOL NUMBER

DET	REQ	NAME	FINISHED SIZE	MAT'L	HEAT TR	MAT'L USED	WT OR FT	UNIT PRICE	TOTAL
38	1	FILTER ELEMENT	PUROLATOR			7509200			
37	1	FILTER	PUROLATOR			7509600			
36	2	FITTING	SWAGELOK			#400-6-4AN			
35	2	FITTING	ORDERED AS	PART	of	DET #29			
34	2	FITTING TEE	SWAGELOK			#400-3-4TTF			
33	2	FITTING	SWAGELOK			#600-1-OR			
32	1	REGULATOR	TESCOM		△2	26-2322-34-064	0-250 PSIG		
31	1	THERMOMETER	MARHALLTOWN			#99	20-240° 2" DIAL, 2½" STEM		
30	1	BLOCK	1X1½X4	ALUM					
29	1	FLOW METER	FLOW TECHNOLOGY INC			FT-8M1-LB △1	0.07 TO 1.1 GPM		
28	1	PRESSURE GAGE	MARSHALLTOWN			#23	DIAL 2½" 0-160 PSI		
27	2	VALVE	WHITEY			#1RS4			
26	1	PRESSURE GAGE	MARSHALLTOWN			#23	DIAL 2½" 0-100 PSI		
25	1	VALVE	WHITEY			#1VS4			
24	1	METAL COVER	MAT'L HANDLING B-311B	STK					
23	1	JAR	MAT'L HANDLING B-310	STK					
22	1	TRAY	1/16X10⅝X14⅝	ALUM		6061-T4			
21	3	POST	3/4 HEX X 4	ALUM					
20									
19									
18									
17									
A3 16	2	VALVE	WHITEY			B-04M2-S2-A	1/8 NPT X 1/8 TUBE		
15	2	THUMB SCR	PIC #4042						
14	4	O' RING	MS28775-005						
13	2	RESTRICTOR	5/16 DIAX 5/32	ALUM					
12	2	O' RING	MS28775-133						
A2 11	1	TEE FITTING	SWAGELOK			B-200-3TMT	1/8 NPT X 1/8 TUBE MALE RUN TEE		
10	3	FITTING	SWAGELOK			#400-1-2	1/8 NPT X 1/4 TUBE		
9	1	HANDLE	BUD H-9168-B						
8	1	PLATE	1/4X2X4	ALUM					
7	1	TOP COVER	2DIAX1/2	ALUM		2024-T3			
6	1	BOTTOM COVER	2¾DIAX3/8	ALUM		2024-T3			
A1 5	1	VALVE	HOKE			#1511 M2B			
4	1	MANIFOLD	1X1X2	ALUM		2024-T3			
3	2	FITTING	SWAGELOK			#200-1-2	1/8 NPT X 1/8 TUBE		
2	1	DIFFERENTIAL PRESSURE TRANSDUCER	VALIDYNE MODEL DP9						
1	1	HOUSING	1⅝X4X4½	ALUM		2024-T3			

TOLERANCES UNLESS NOTED
MACH ∠ ±1° FORMING ∠ ±2°
ONE PLACE DEC = ± .060
TWO PLACE DEC = ± .015
THREE PLACE DEC = ± .005

10049046
REF DWGS

DESIGNED FOR
DRAWN RATA — 3 JUN
DETAILED
CHECKED
SUP'V
ENG

Honeywell

NAME RATE SENSOR TEST FIXTURE

PART — INSTR

OP. — MACH — E O

NO SHEETS 4 — SHEET NO 1 — SIZE D — YG 1158-E106

CHG NO ______ TOOLM ______ BIN ______ CHG TO ______

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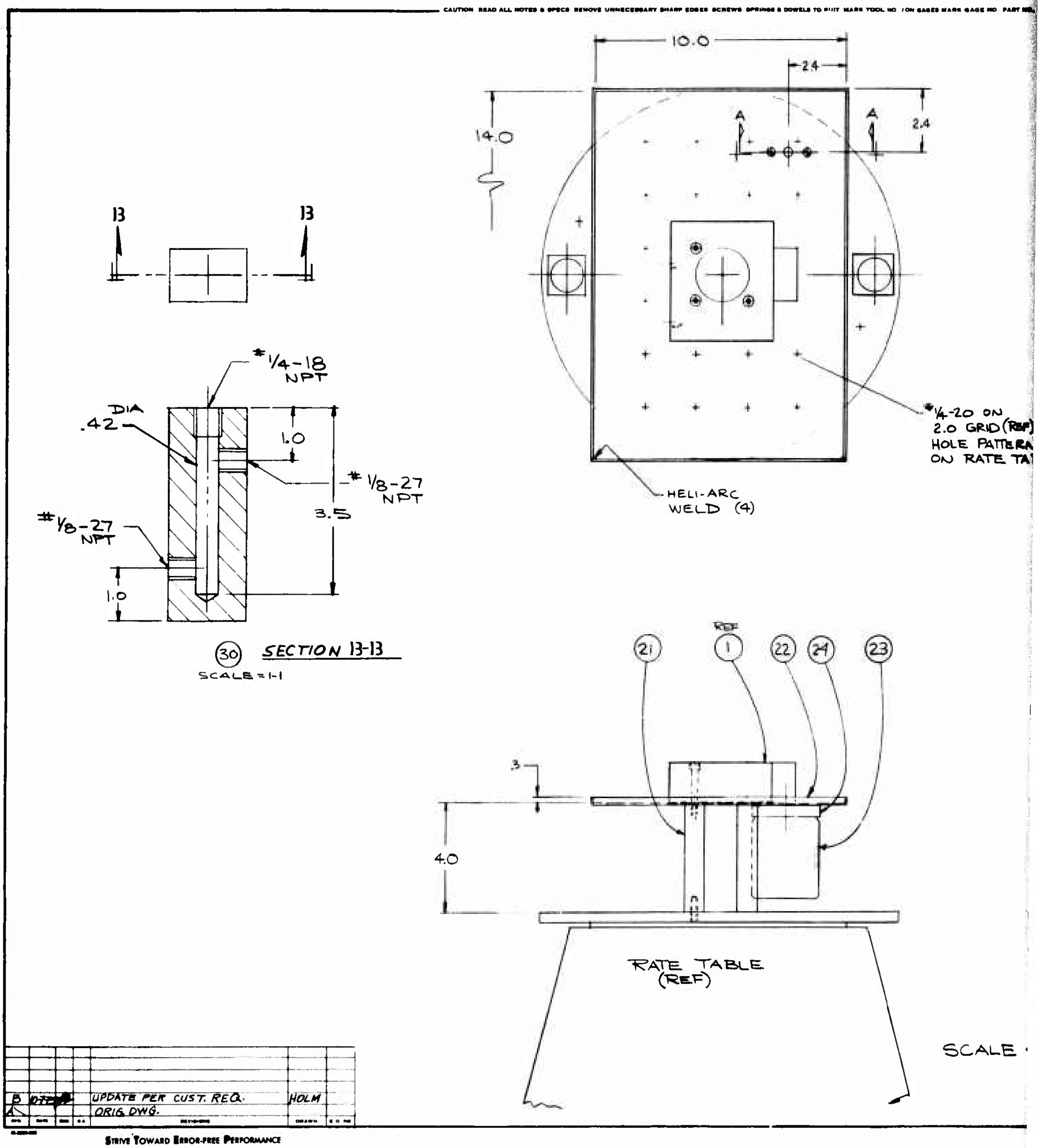
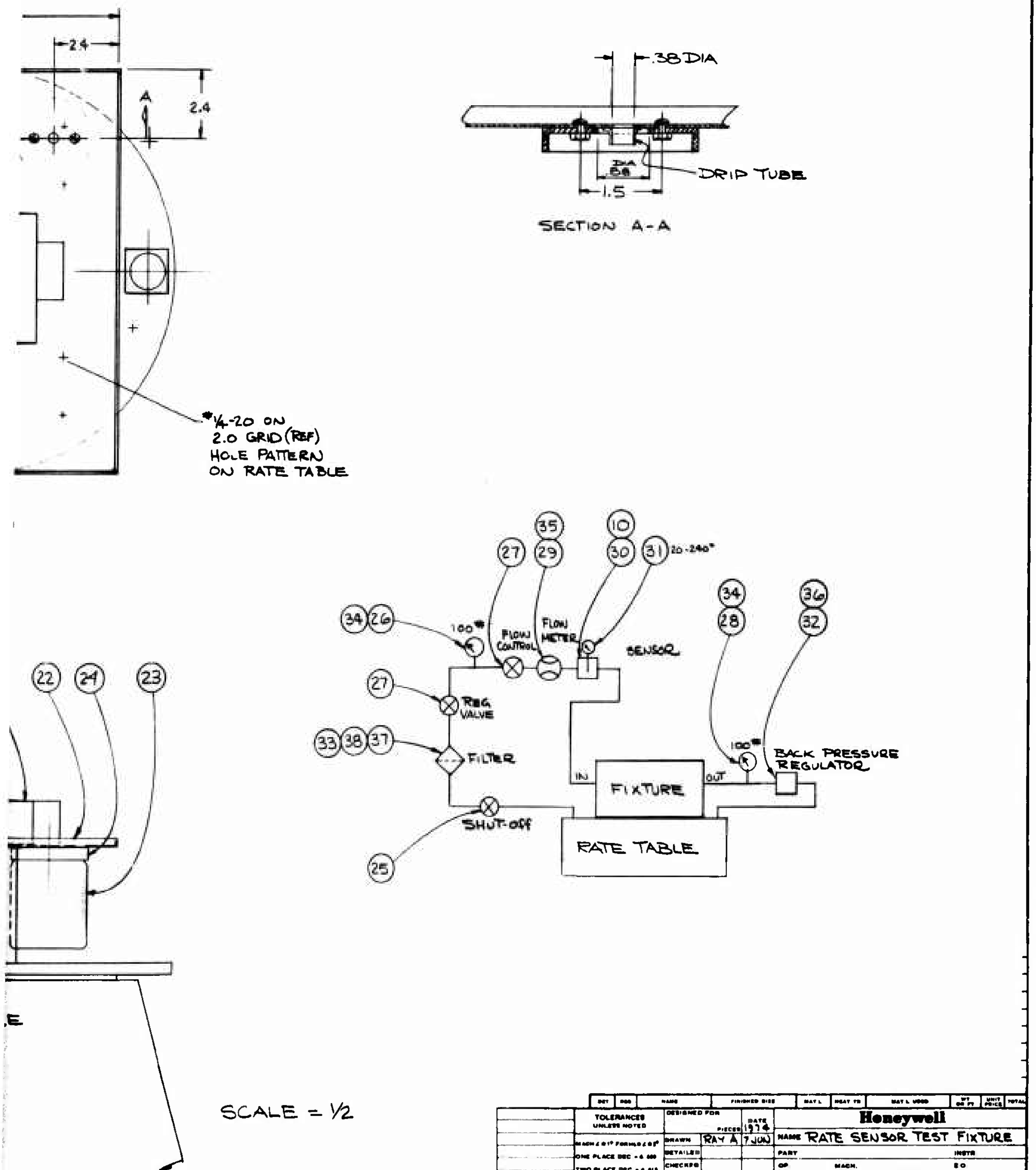


2

DON'T FORGET SAFETY



SCALE = 1/2

TOLERANCES UNLESS NOTED	DESIGNED FOR	Honeywell
	DRAWN RAY A 7 JUN 1974	NAME RATE SENSOR TEST FIXTURE
	DETAILED	PART
	CHECKED	
	SUP'V	NO SHEETS 4 SHEET NO 2 SIZE D YG1158-E106
	ENG QC	

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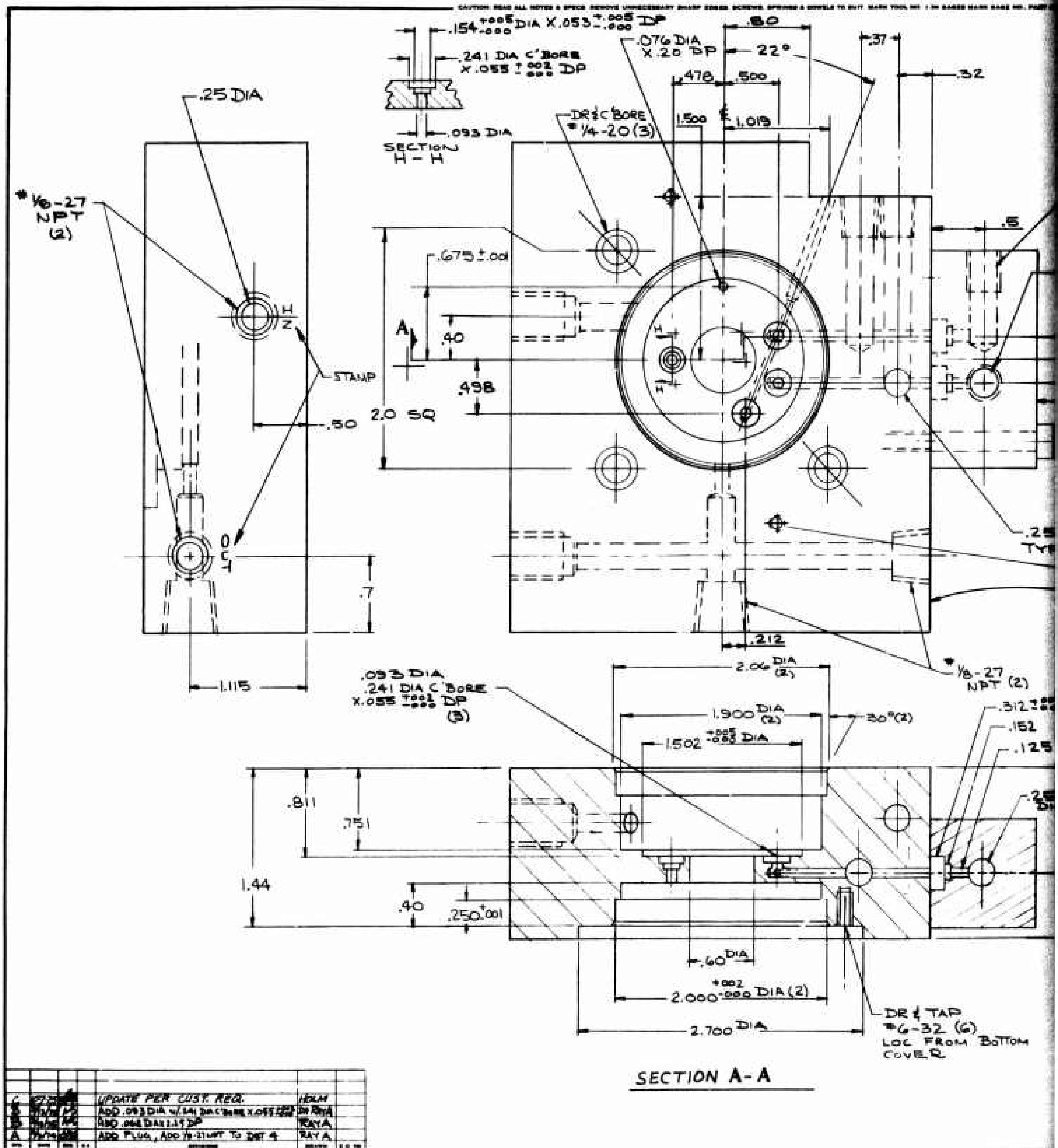
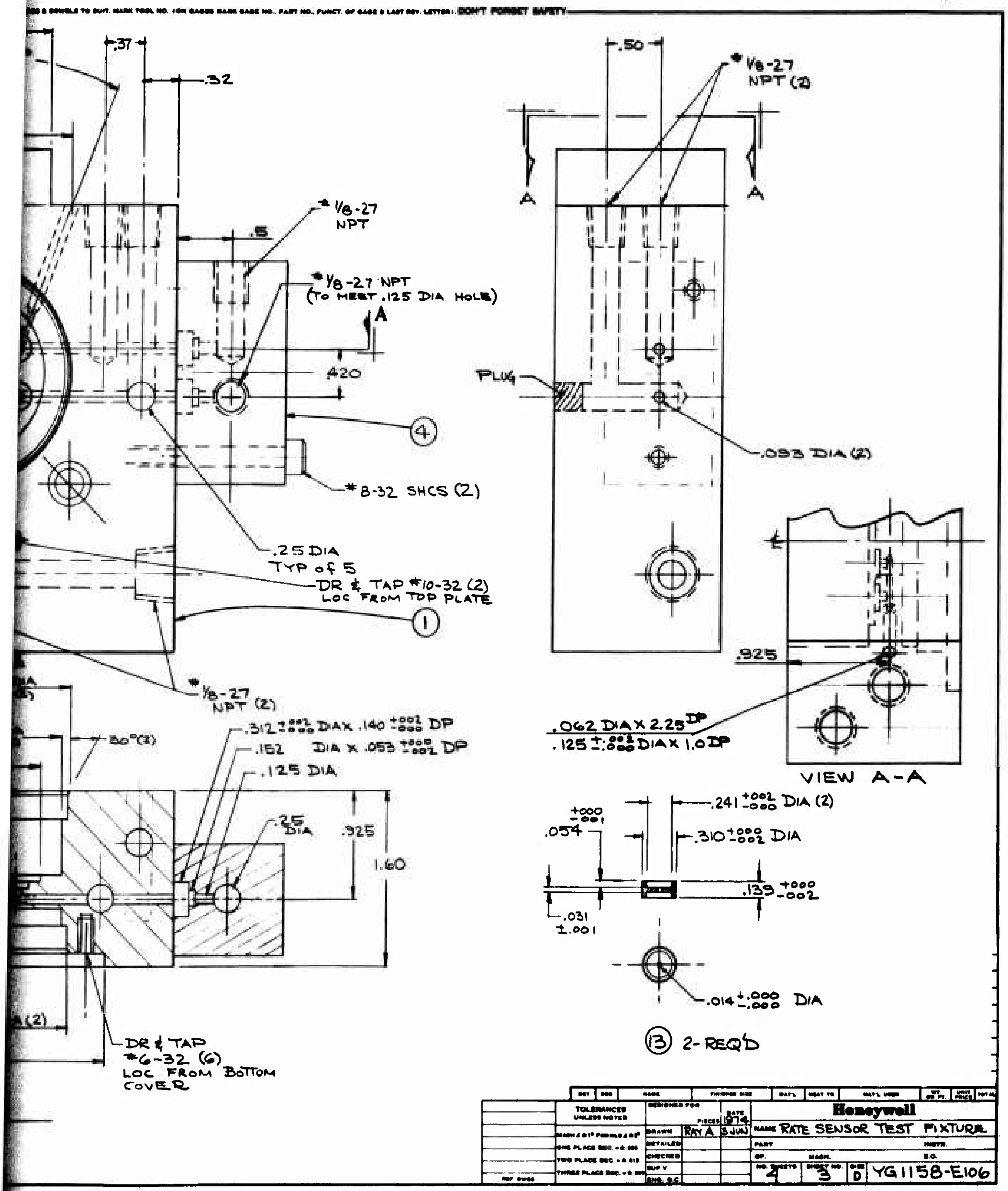


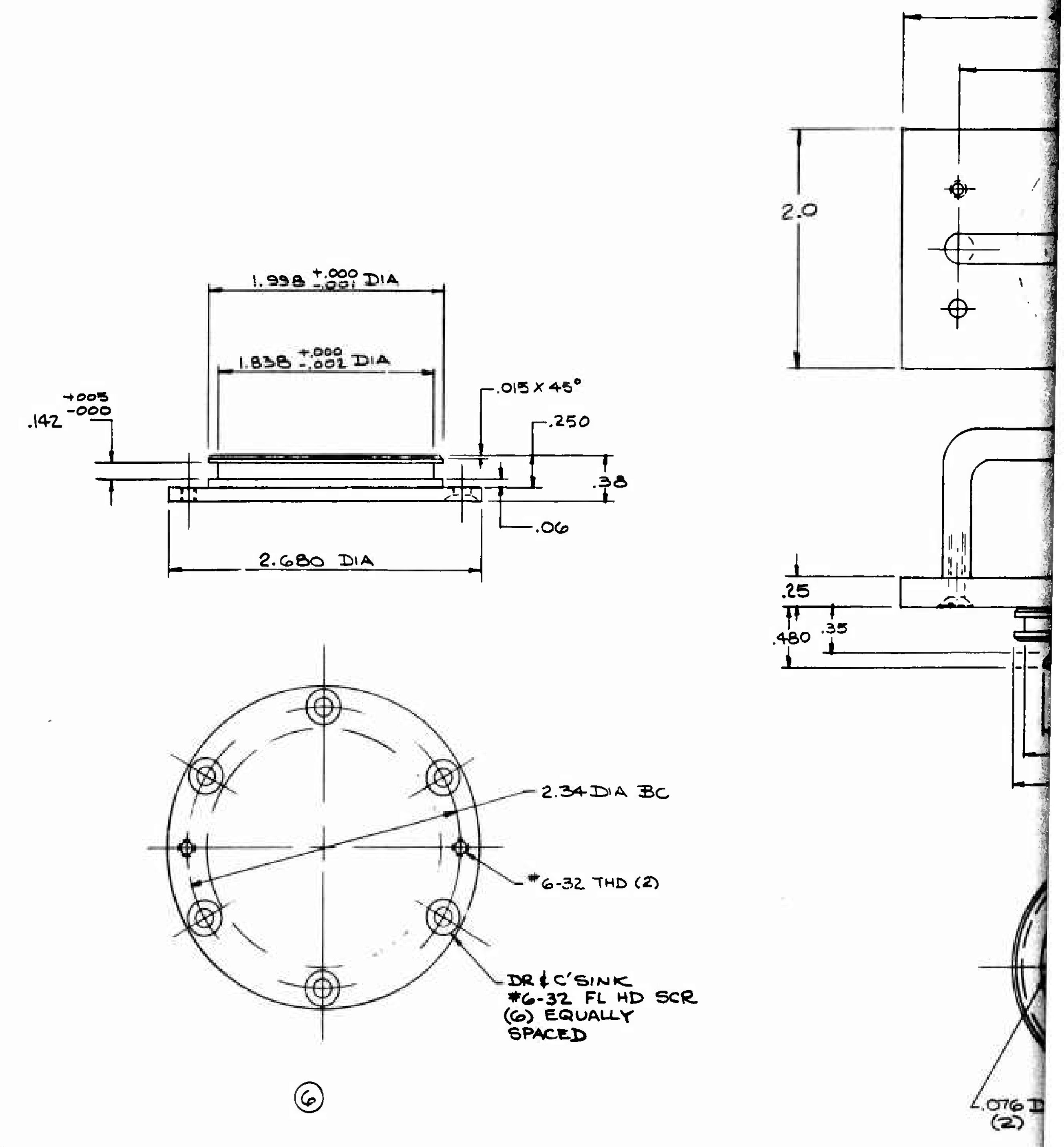
STRIVE TOWARD ERROR-FREE PERFORMANCE

2


DON'T FORGET SAFETY
.37
.32
.50
* 1/8-27 NPT (2)
A
A
* 1/8-27 NPT
.5
* 1/8-27 NPT (TO MEET .125 DIA HOLE)
A
.420
PLUG
4
.093 DIA (2)
* 8-32 SHCS (2)
.25 DIA TYP of 5
DR & TAP * 10-32 (2) LOC FROM TOP PLATE
1
.925
* 1/8-27 NPT (2)
.312 +.002 -.000 DIA X .140 +.002 -.000 DP
30° (2)
.152 DIA X .053 +.000 -.002 DP
.125 DIA
.062 DIA X 2.25 DP
.125 +.002 -.000 DIA X 1.0 DP
VIEW A-A
.25 DIA
.925
1.60
.241 +.002 -.000 DIA (2)
+.000 -.001 .054
.310 +.000 -.002 DIA
.139 +.000 -.002
.031 ±.001
.014 +.000 -.000 DIA
13 2-REQ'D
DR & TAP * 6-32 (6) LOC FROM BOTTOM COVER
TOLERANCES UNLESS NOTED
DESIGNED FOR
PIECES
DATE 1974
DRAWN RAY A 3 JUN
DETAILED
CHECKED
Honeywell
NAME RATE SENSOR TEST FIXTURE
PART
NO. SHEETS 4
SHEET NO. 3
D
YG1158-E106

PRECEDING PAGE BLANK-NOT FILMED

CAUTION: READ ALL NOTES & SPECS REMOVE UNNECESSARY SHARP EDGES SCREWS, SPRINGS & DOWELS TO SUIT MARK TOOL NO. ...



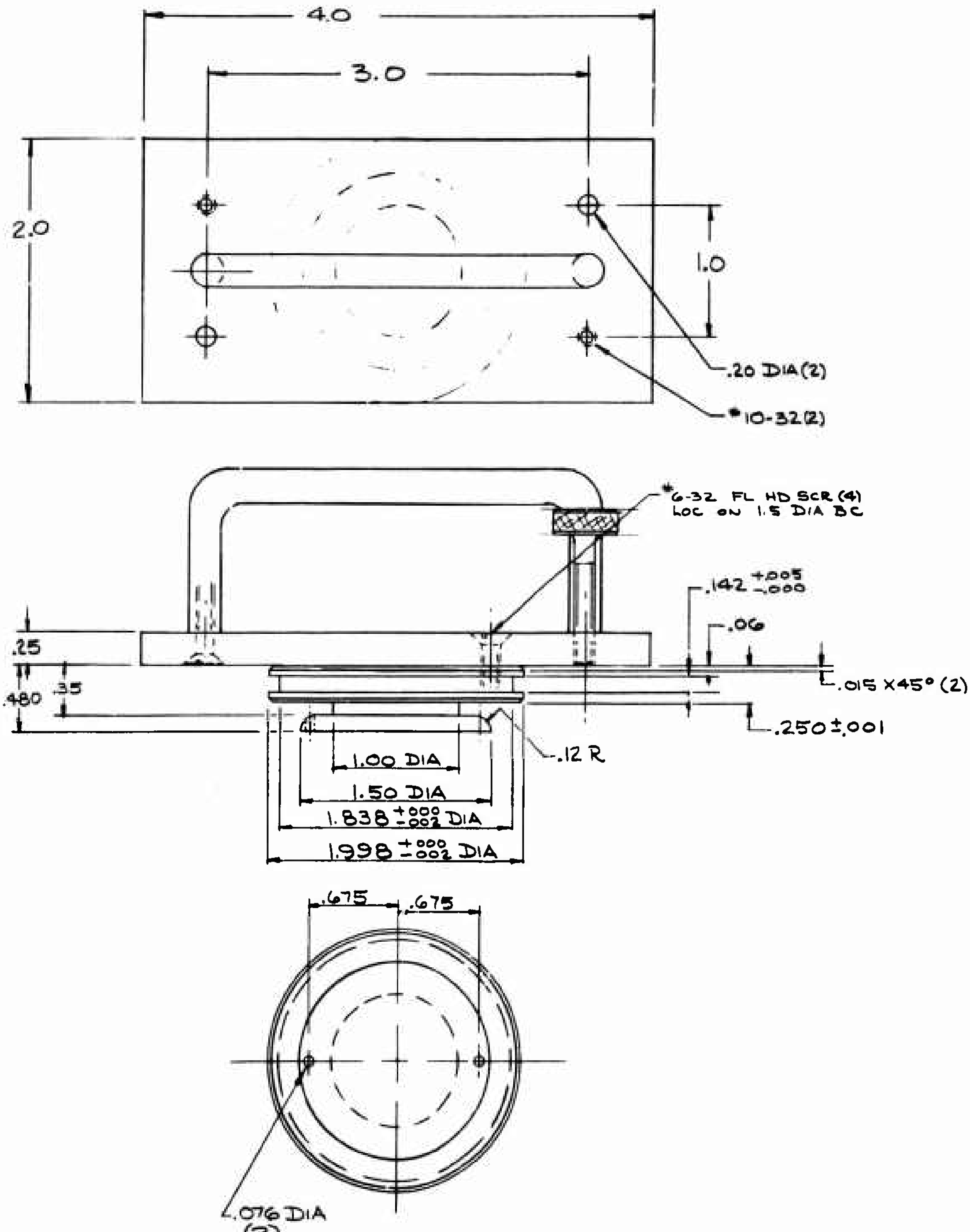
B UPDATE PER CUST. REQ. HOLM

A ORIG. DWG.

STRIVE TOWARD ERROR-FREE PERFORMANCE

2

DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO., PART NO., FUNCT. OF GAGE & LAST REV LETTER) DON'T FORGET SAFETY



7 8 9 15

TOLERANCES UNLESS NOTED	DRAWN: RAY A	DATE: 1974 3 JUN	Honeywell
			NAME: RATE SENSOR TEST FIX
10047446			
10050036			
			NO SHEETS 4 · SHEET NO 4 · SIZE D · YG1158-E106

CHG NO ______ TOOL# ______ BIN ______ CHG. TO ______

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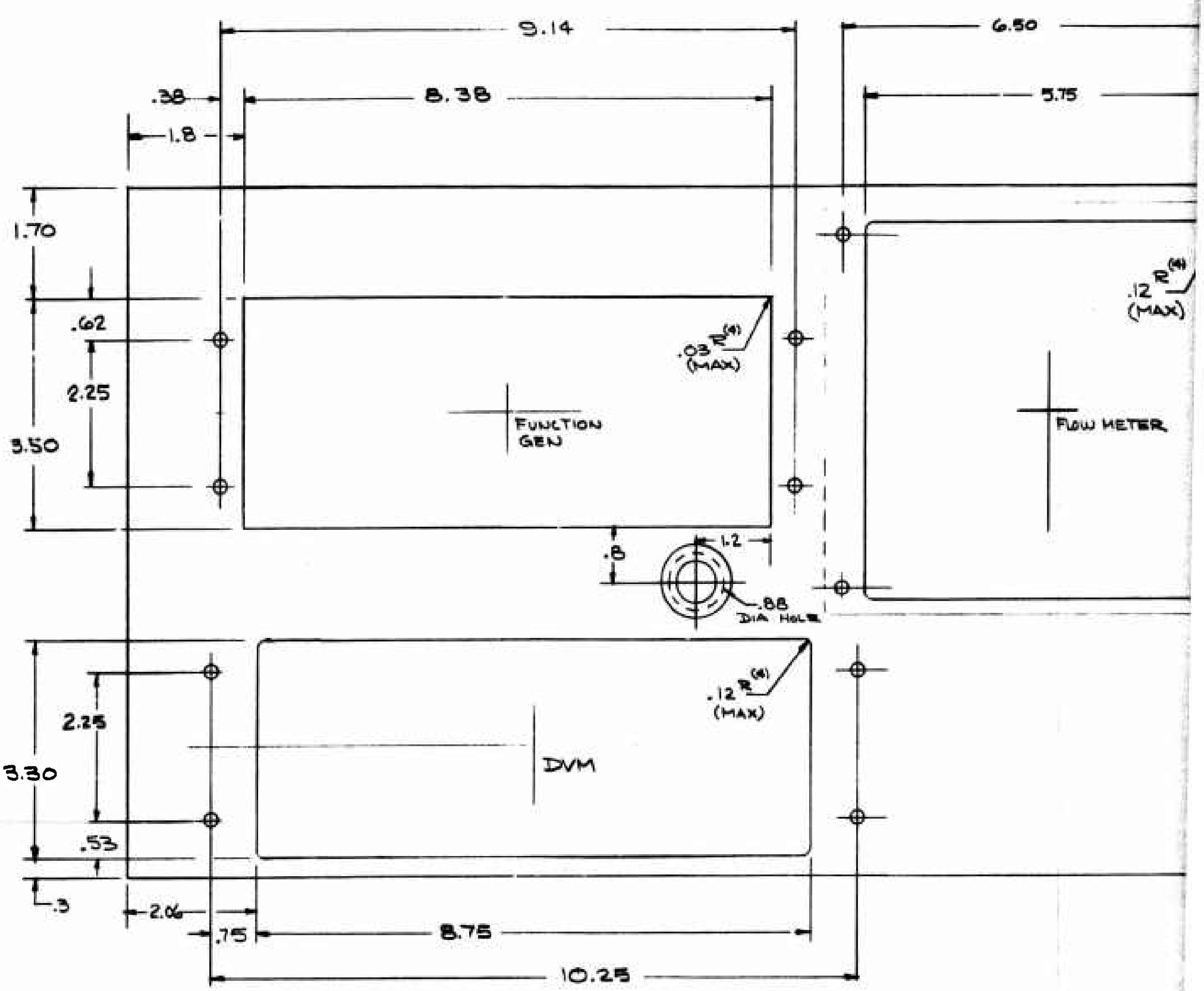
CAUTION: READ ALL NOTES & SPECS. REMOVE UNNECESSARY SHARP EDGES. SCREWS, SPRINGS & DOWELS TO SUIT. MARK TOOL NO. (ON GAGES MARK GAGE NO.)

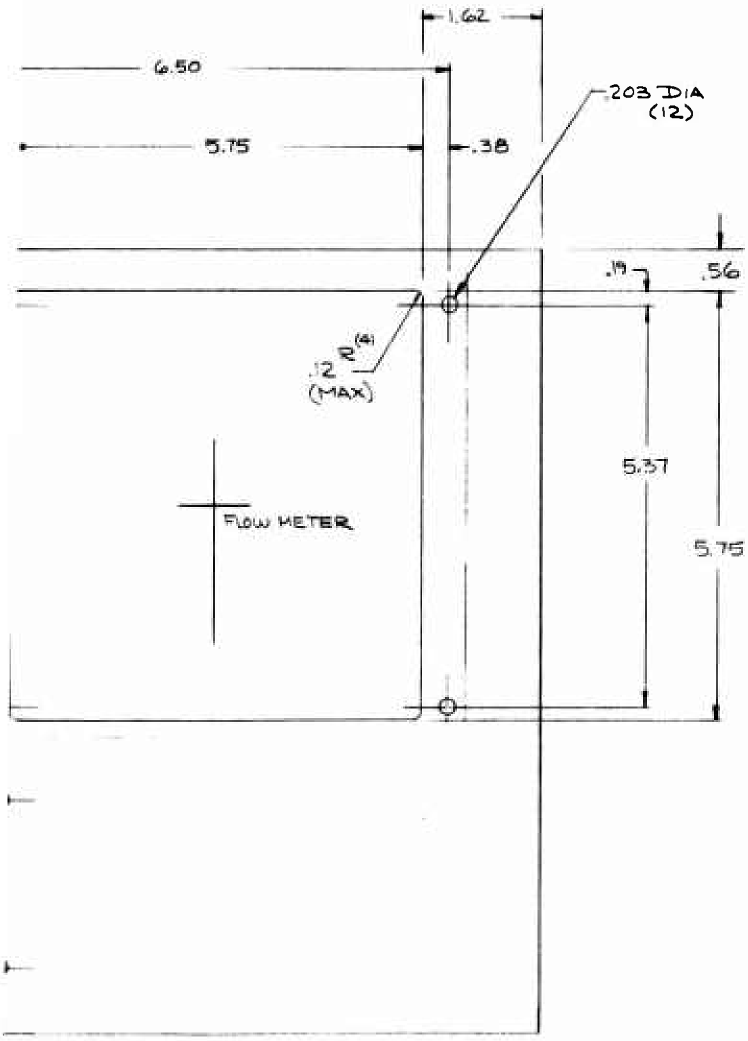


B	4775			UPDATE PER CUST. REQ.	HOLM	
A				ORIG. DWG.		
LTR.	DATE			REVISIONS	DRAWN	E.O. NO.

STRIVE TOWARD ERROR-FREE PERFORMANCE

2

SPRINGS & DOWELS TO SUIT MARK TOOL NO (ON GAGES MARK GAGE NO PART NO FUNCT OF GAGE & LAST REV LETTER) DON'T FORGET SAFETY



⚠ FINISH ~ CLEAR ANODIZE

DET	REQ	NAME	FINISHED SIZE		MAT'L	HEAT TR	MAT'L USED	WT OR FT	UNIT PRICE	TOTAL
5	1	FLOW RATE MONITOR	FLOW TECHNOLGY, INC	#PRI-102A			PUR			
4	1	DVM	KEITHLEY INST. MODEL 165							
3	1	FUNCTION GENERATOR	SYSTRON DONNER #400							
2	1	GROMMET	5/8" ID							
1	1	PANEL	BUD # PA-1106 ⚠				PUR			

REF DWGS	TOLERANCES UNLESS NOTED	DESIGNED FOR PIECES	DATE 1974	Honeywell
	MACH ∠ ±1° FORMED ∠ ±1°	DRAWN RAY A	8 AUG	NAME INSTRUMENT PANEL
	ONE PLACE DEC ± .020	DETAILED		PART INSTR
	TWO PLACE DEC ± .010	CHECKED		OP MACH E O
	THREE PLACE DEC ± .005	SUP V		NO SHEETS 1 SHEET NO 1 SIZE D YG1158-E107
		ENG QC		

CHG NO TOOLM BIN CHG TO

12690-75